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(54) **Image encoding and decoding method and apparatus, and recording medium in which program therefor is recorded**

(57) The invention relates to an image encoding/decoding method, apparatus thereof and a recording medium in which a program therefor is recorded, whereby the encoding/decoding can be obtained with high image quality at high speed. In an image encoding method which comprises producing a DC image composed of each block mean value by dividing an image data per B pixel into a block, making a part of said DC image a DC nest, and where the differential vector $<d_j>$ which is obtained by separating the DC value DC_J from the pixel block $<R_j>$ to be encoded is over an allowable value Z, calculating one or more orthogonal basis ($\alpha_k <V_k>$), to which the differential vector is approximated, by the adaptive orthogonal transform (AOT) using the DC nest, each of the lowest n ($n = \log_2 B$) bits of base extraction blocks $<U_i>$ which are down-sampled from the DC nest is set to 0 . Further, base extraction vectors $<u_i>$are produced by separating a block mean value a_i from the base extraction blocks $<U_i>$.

BLOCK DIAGRAM OF CONVENTIONAL IMAGE ENCODING APPARATUS

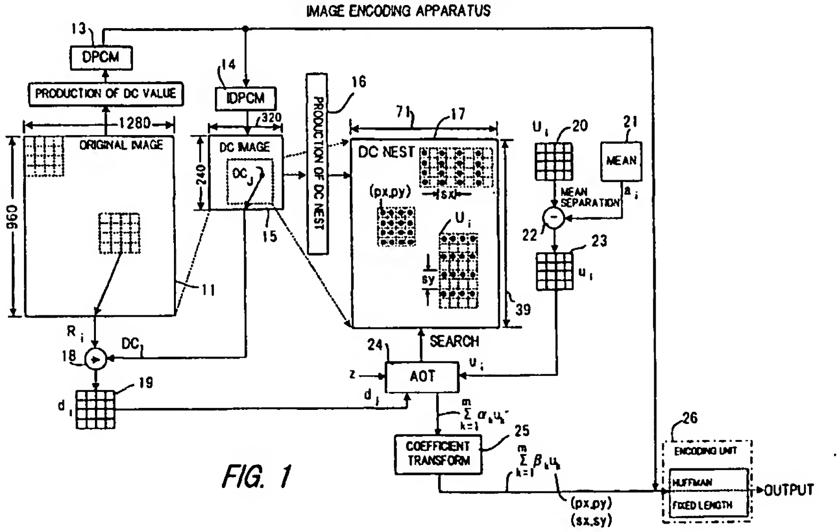

FIG. 1

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Description

[0001] The present invention relates to an image encoding/decoding method, an apparatus thereof, and a recording medium in which a program therefor is recorded, and more particularly, relates to an image encoding/decoding method, an apparatus thereof, and a recording medium in which a program therefor is recorded, according to Hybrid Vector Quantization (HVQ) system.

[0002] According to JPEG (Joint Photographic Expert Group) system, 8 times 8 pixel blocks are converted to DC (direct current) value and each coefficient value of from base to 63 times frequency by two dimensional DCT (discrete cosine transform), and information amount is reduced by quantizing the coefficient value in a different quantization width within no reduction of image quality utilizing frequency components of natural images which are gathered in a low frequency range, and then Huffman encoding is carried out.

[0003] According to HVQ system, which is a kind of mean value separation type block encoding same as JPEG, adaptive orthogonal transform (AOT) which is an intermediate system between a vector quantization and orthogonal transform encoding is used as a compression principle. AOT is a system in which the minimum number of non-orthogonal basis is selected from nests of the basis corresponding to a code book of vector quantization and the objective blocks become close to the desired and allowable error "Z". According to the HVQ system, decoding is quickly carried because a decoding operation can be done in the form of integer. Natural images and artificial images (animation images, CG images) can be compressed in high image quality, because there are not mosquito and block noise, which are particularly generated in JPEG, and false contour, which is particularly generated in GIF. The invention relates to a method for further improving the image quality and for carrying out the coding operation at a higher speed in the HVQ system.

[0004] The applicants of the invention have proposed an image encoding/decoding method in accordance with the HVQ system utilizing self-similarity of images in Japanese Patent Application No. 189239/98. The contents of such proposal will be explained as follows. In the disclosure, a sign<a>means vector "a" or block "a", a sign $\|a\|$ means norm of the vector "a", and a sign $<a \cdot b>$ means inner product of vectors a and b. Further, vectors and blocks in drawings and [numbers] are represented by block letters.

[0005] Fig. 1 is a block diagram showing a conventional image encoder. In Fig. 1, 11 is an original image memory for storing an original image data, 12 is a DC value production unit for seeking a block average (DC) value per each pixel block (4 times 4 pixel) of the original image data, 13 is a differential PCM encoding unit (DPCM) for carrying out a differential predict encoding per each DC value, 14 is inverse DPCM encoding unit for decoding each DC value from the differential PCM encoding, 15 is a DC image memory for storing a decoded DC image, 16 is a DC nest production unit for cutting off the DC nest of a desired size from a part of the DC image, and 17 is a DC nest memory for storing the DC nest.

[0006] Further, 18 is a subtractor for separating a corresponding decoding DC value "DC_J" from a target image block $<R_J>$ to be encoded, 19 is a differential vector buffer for storing a differential vector $<d_j>$ which is DC separated, 20 is an extracted block buffer for storing a base extraction block $<U_i>$ of 4 times 4 pixels which is down-sampled from the DC nest, 21 is an equilibrator for seeking a block mean value a_i of the base extraction block $<U_i>$, 22 is a subtractor for separating the block means value a_i from the base extraction block $<U_i>$, 23 is an extracted vector buffer for storing the base extraction block $<U_i>$ which is separated by the mean value, 24 is an adaptive orthogonal transform (AOT) processing unit for producing an orthogonal basis $\alpha_k <u_k'>$ (k=1~m) to search the DC nest to make the differential vector $<d_j>$ closer to the allowable error Z, where a square norm $\|d_j\|^2$ of the differential vector is over the allowable error Z, 25 is a coefficient transform unit for seeking an expanding square coefficient β_k which is multiplied by a non-orthogonal basis vector $<u_k>$ (k=1~m) per the produced orthogonal basis $\alpha_k <u_k'>$ (k=1~m) to produce an equivalent non-orthogonal basis $\beta_k <u_k>$ (k=1~m), and 26 is an encoding unit by Huffman coding, run length coding or fixed length coding system for the compression encoding of information such as DPCM encoding of the DC value or the non-orthogonal basis $\beta_k <u_k>$.

[0007] In the DC value production unit 12, the block mean value of 4 times 4 pixels is provided in which the first decimal place is rounded off or down. In the DPCM 13, where the DC value of row J and column T is shown by the $DC_{J,I}$, a predictive value $DC_{J,I}'$ of the $DC_{J,I}$ is provided by the formula, $DC_{J,I}' = (DC_{J,I-1} + DC_{J-1,I})/2$, and its predictive error $(\Delta DC_{J,I} = DC_{J,I} - DC_{J,I}')$ is linear-quantized by a quantization coefficient Q(Z) and is output. The quantization coefficient Q(Z) corresponds to the allowable error Z and is variable within the range of 1 to 8 according to the allowable error Z.

[0008] In the DC nest production unit 16, the DC nest is prepared by copying the range of vertical 39 x horizontal 71 from the DC image. It is preferred that the DC nest includes more alternating current components because it is used as a codebook. Therefore, it is prepared by copying such the range that the sum of absolute values of difference between the DC values adjacent to each other in a plurality of the extracted ranges become maximum.

[0009] In making down- samples of the base extraction block$<U_i>$, a vertex per one DC value in vertical and horizontal section is set to $(p_x, p_y) \in [0, 63]\times[0, 31]$and a distance of its sub-samples is set to 4 kinds of $(s_x, s_y) \in \{(1, 1), (1, 2),$

(2, 1) , (2, 2) } . Accordingly, the total numbers of the base extraction blocks<U_i>are N (= 8192) and are referred by an index counter "i" from the AOT 24. Behavior of conventional adaptive orthogonal transform processing unit 24 will be explained below.

[0010] Fig. 2 is a flow chart of conventional adaptive orthogonal transform processing and Fig. 3 is an image drawing of the processing. In Fig. 2, it is input in the processing that the square norm $\| d_j \|^2$ of the differential vector is more than Z. In step S121, the square norm $\| d_j \|^2$ of the differential vector is set in a resister E. A basis number counter is initialized to k = 1. In step S122, much value (e.g. 100,000) is set in a minimum value holding resister E'. In step S123, an index counter of the base extraction block<U_i>is initialized to i = 0. By these steps, the initial address and distance of sub-samples in the DC nest are set to $(p_x, p_y) = (0, 0)$ and $(s_x, s_y) = (1, 1)$, respectively.

[0011] In step S124, the base extraction vector <u_i> is produced by separating the block mean value a_i from the base extraction blocks<U_i>. Since the operation or calculation is carried out under the accuracy of integer level, any value of first decimal place in the block mean value a_i is rounded off or down. In step S125, the base extraction vector<u_i>is subjected to orthogonal transform processing to be converted to the orthogonal basis vector<u_k'>, if necessary (k > 1).

[0012] Fig. 3 (A) and (B) are image drawings of the orthogonal transform processing. In Fig. 3 (A), the first base extraction vector<u_1>can be the first basis vector<u_1'>as it is.

[0013] Then, the second base extraction vector<u_2>is subjected to orthogonal transform processing to be converted to the second basis vector<u_2'>in accordance with the following method. That is, a shadow of the second base extraction vector<u_2> projected on the first basis vector<u_1'>is represented by the formula (1).

[Numeral 1]

[0014]

$$\|u_2\|\cos\theta = \frac{\langle u_1' \cdot u_2 \rangle}{\|u_1'\|} \qquad \because \langle u_1' \cdot u_2 \rangle = \|u_1'\|\|u_2\|\cos\theta \tag{1}$$

[0015] Accordingly, the second orthogonal vector <u_2'> is obtained by subtracting the vector of the projected shadow from the second base extraction vector<u_2>.

[Numeral 2]

[0016]

$$u_2' = u_2 - \frac{\langle u_1' \cdot u_2 \rangle \; u_1'}{\|u_1'\| \; \|u_1'\|} \tag{2}$$

[0017] In Fig. 3 (B), the third base extraction vector <u_3> is subjected to orthogonal transform processing to the first basis vector<u_1'>and the second basis vector<u_2'>.

[0018] Fig. 3 is three-dimensionally drawn. The third base extraction vector<u_3>is subjected to orthogonal transform processing to the first basis vector <u_1'> to obtain an intermediate orthogonal vector<u_3">.

[Numeral 3]

[0019]

$$u_3'' = u_3 - \frac{\langle u_1' \cdot u_3 \rangle}{\|u_1'\|^2} \, u_1' \tag{3}$$

[0020] Further, the intermediate orthogonal vector<u3">is subjected to orthogonal transform processing to the second basis vector<u_2'>to obtain the third basis vector <u_3'>.

[Numeral 4]

[0021]

$$
\begin{aligned}
\mathbf{u}_3' &= \mathbf{u}_3'' - \frac{\langle \mathbf{u}_2' \bullet \mathbf{u}_3'' \rangle}{\|\mathbf{u}_2'\|^2}\mathbf{u}_2' \\
&= \left(\mathbf{u}_3 - \frac{\langle \mathbf{u}_1' \bullet \mathbf{u}_3 \rangle}{\|\mathbf{u}_1'\|^2}\mathbf{u}_1'\right) - \frac{\left\langle \left(\mathbf{u}_3 - \frac{\langle \mathbf{u}_1' \bullet \mathbf{u}_3 \rangle}{\|\mathbf{u}_1'\|^2}\mathbf{u}_1'\right) \bullet \mathbf{u}_2' \right\rangle}{\|\mathbf{u}_2'\|^2}\mathbf{u}_2' \\
&= \mathbf{u}_1 - \frac{\langle \mathbf{u}_1' \bullet \mathbf{u}_3 \rangle}{\|\mathbf{u}_1'\|^2}\mathbf{u}_1' - \frac{\langle \mathbf{u}_2' \bullet \mathbf{u}_3 \rangle}{\|\mathbf{u}_2'\|^2}\mathbf{u}_2'
\end{aligned}
\qquad (4)
$$

[0022] Turning to Fig. 2, in step S126, a scalar coefficient α_i is calculated using the orthogonal vector$<u_i'>$so that a distance with the differential vector$<d_k>$ (at first$<d_j>$) becomes minimum.

[0023] Fig. 3 (C) is an image drawing of the orthogonal transform processing. In Fig. 3 (C), where a differential vector represented by$<d_k>$is subjected to approximation, a square norm thereof ($e_i = \| <d_k> - \alpha_i <u_i'> \|^2$) is minimum when the product of the orthogonal vector$<u_i'>$and the scalar coefficient α_i is diagonal with the differential vector $\{<d_k>-\alpha_i <u_i'>\}$ as shown in Fig. 3 (C) (inner product = 0). Accordingly, the scalar coefficient α_i is obtained by the formula (5).

[Numeral 5]

[0024]

$$\langle \alpha_i u_i' \cdot (d_k - \alpha_i u_i') \rangle = 0 \quad \alpha_1 \langle u_1' \cdot d_k \rangle - \alpha_1^2 \langle u_1' \cdot u_1' \rangle = 0 \qquad (5\text{-}1)$$

$$\alpha_1 = \frac{\langle d_k \cdot u_1' \rangle}{\|u_1'\|^2} \qquad (5\text{-}2)$$

[0025] It is shown in the drawing that the differential vector$<d_k>(k=0)$ is subjected to approximation to other first base extraction vector$<u_j'>$. The first base extraction vector$<u_j'>$is shown by the image drawing because it can take optional directions.

[0026] Turning to Fig. 2, in step S127, a square norm (e_i) of error vector is obtained by the formula (6) after the differential vector$<d_k>(k=0)$ is subjected to approximation to the base extraction vector $\alpha_i<u_j'>$.

[Numeral 6]

[0027]

$$\begin{aligned} e_i &= \left\| \mathbf{d}_k - \alpha_i \mathbf{u}_i' \right\|^2 \\ &= \left\| \mathbf{d}_k \right\|^2 - 2\alpha_i \langle \mathbf{d}_k \bullet \mathbf{u}_i' \rangle + \alpha_i^2 \left\| \mathbf{u}_i' \right\|^2 \\ &= \left\| \mathbf{d}_k \right\|^2 - 2\frac{\langle \mathbf{d}_k \bullet \mathbf{u}_i' \rangle^2}{\left\| \mathbf{u}_i' \right\|^2} + \frac{\langle \mathbf{d}_k \bullet \mathbf{u}_i' \rangle^2}{\left\| \mathbf{u}_i' \right\|^4} \left\| \mathbf{u}_i' \right\|^2 \\ &= \left\| \mathbf{d}_k \right\|^2 - \frac{\langle \mathbf{d}_k \bullet \mathbf{u}_i' \rangle^2}{\left\| \mathbf{u}_i' \right\|^2} \\ &= E - \frac{\langle \mathbf{d}_k \bullet \mathbf{u}_i' \rangle^2}{\left\| \mathbf{u}_i' \right\|^2} \end{aligned} \qquad (6)$$

[0028] In step S128 of Fig. 2, it is judged whether e_i is less than E' or not. If e_i is less than E', content of E' is renewal in step S129 and the information regarding α_i, <u_i'>, <u_i>, etc. at the time is held in an arrangement [α_k], [u_k'], [u_k], etc. If e_i is not less than E', the processing in step S129 is skipped.

[0029] In step S130, one (1) is added to the counter i, and in step S131, it is judged whether i is not less than N (= 8192) or not. If i is less than N, turning to step 124 and the same processing is carried out with respect to next base extraction vector<u_i>.

[0030] The processing is repeated and when it is judged in step S131 that i is not less than N, all base extraction vectors<u_i>have been completely tried. At the time, the register E' holds the minimum square norm e_i.

[0031] It is judged in step S132 whether E' is not more than Z or not. If E' is more than Z, it is treated as E = E' in step S133. That is, the square norm of the differential vector is renewal. In step S134, one (1) is added to the counter k, turning to step S122. If E' is not more than Z, this processing is skipped. Thus, the orthogonal basis α_k<u_k'>(k = 1 ~ m) to approximate the difference of the first differential vector<d_j>to the allowable error Z is obtained.

[0032] However, the block mean value a_j of the base extraction block<U_j>has been rounded off or down in the conventional methods and therefore, improvement of image quality is limited. Why the conventional methods are inconvenient will be explained according to Fig. 4.

[0033] Fig. 4 is an image drawing of mean value separation processing. A relationship of base extraction block<U_j> (vertical axis) with the pixel value of certain row (horizontal axis) is shown in Fig. 4 (a). An actual pixel value is a block mean value of 16 pixels, but the block mean value of 4 pixels will be used to simplify the explanation herein. In Fig. 14 (a), each pixel value is 5, 2, 4, and 3 and its mean value a_j is 3.5. when the first decimal place is round down, the block mean value a_j of the base extraction block<u_j>is 0.5 as shown in Fig. 4(b). In Fig. 4 (c), if the basis vector β_k <u_k>is added to the DC value DC_J of the decoded block, the DC component (a_j = 0.5) is overlapped on the target block<R_j>. In case that the number of basis is plural, the DC value is overlapped on the DC_J by various values in the range of $0<a_j<1$, and as a result, certain noise is overlapped per each block in the decoded image, whereby image quality is not improved. This disadvantage also occurs in case that the first decimal place is rounded off or up.

[0034] According to the conventional AOT processing, much operations and much time are required, because all of the base extraction vectors<u_j>must be subjected to orthogonal processing to the preceding base vectors<u_k'>.

[0035] It is therefore an object of the invention to provide an image encoding/decoding method, which provides high image quality at high speed, an apparatus thereof and a recording medium in which such program therefor is recorded.

[0036] The above object of the invention can be solved by the construction, for example, as shown in Fig. 5. That is, the image encoding method of the invention (1) comprises producing a DC image composed of each block mean value by dividing an image data per B pixel into a block, making a part of said DC image a DC nest, and where the

differential vector$\langle d_j \rangle$which is obtained by separating the DC value DC_J from the pixel block to be encoded is over an allowable value Z, calculating one or more orthogonal basis (e.g. $\alpha_k \langle v_k \rangle$) , to which the differential vector$\langle d_j \rangle$is approximated, by the adaptive orthogonal transform (AOT) using the DC nest, wherein the lowest n ($n = \log_2 B$) bits of the DC pixel in each sample being set to 0, where the base extraction block is down-sampled from the DC nest and the block mean value a_i of it is calculated using the samples.

[0037] Accordingly, any fraction less than 1 does not occurs in the block mean value a_i and the block mean value a_i with integer level precision is obtained at high speed.

[0038] In a preferred embodiment of the invention (1) that is the invention (2) , the lowest n bits of the DC pixel is set to 0 or is masked, where the DC nest is produced from the DC image.

[0039] Accordingly, the DC nest, of which the lowest n bits of the DC pixel is set to 0 or is masked, is efficiently obtained by one processing.

[0040] In a preferred embodiment of the invention (1) or (2) that is the invention (3) , abase extraction vector$\langle u_i \rangle$is produced to which the differential vector$\langle d_j \rangle$approximates by separating the block mean value a_i from the base extraction block$\langle U_i \rangle$in which the lowest n bits of the DC pixel is set to 0.

[0041] According to the invention (3), the sum (the block mean value) of all elements in such base extraction vectors$\langle u_i \rangle$is always 0 and the DC component is completely separated. Therefore, even if the base vectors$\langle u_k \rangle$are piled up on each other in the decoding side, unnecessary DC component (noise) does not cause. The image quality in the HVQ system is more improved by the invention (3).

[0042] In a preferred embodiment of the invention (3) that is the invention (4), optional elements (e.g. u_{16}) of base extraction vectors$\langle u_i \rangle$are replaced by linear bond of the remainder elements and the inner product of the base extraction vectors$\langle u_i \rangle$and the other optional vectors$\langle w \rangle$are calculated by the formula.

$$\langle w \cdot u_i \rangle= (w_1-w_{16})\,u_1 + (w_2-w_{16})\,u_2 + \cdots + (w_{15}-w_{16})\,u_{15}$$

[0043] In the invention (4), the sum of all elements in the base extraction vectors$\langle u_i \rangle$is always 0 and hence, the optional elements (e.g. u_{16}) are represented by the linear bond of the remainder elements. Accordingly, the inner product calculation$\langle w \cdot u_i \rangle$with the other optional vectors (w) can be expanded to the product-sum calculation as shown by the above formula, whereby a single round of such complicated calculation can be omitted. Since much inner product calculation of the vectors is conducted in the image encoding method according to the HVQ system, such single round omission of the calculation contributes to high speed encoding processing.

[0044] In a preferred embodiment of the invention (3) or (4) that is the invention (5), a first basis is searched so that h_i may be maximum in the following formula,

$$h_i = \langle d \cdot u_i \rangle^2 / \| u_i \|^2$$

wherein$\langle d \rangle$is the differential vectors and$\langle u_i \rangle$is the base extraction vectors. According to the invention (5), such condition that square norm $\| \langle d \rangle - \langle \alpha_i u_i \rangle \|^2$ of the difference with the differential vectors$\langle d \rangle$is minimum can be searched by the above simple calculation. Hence, the AOT processing can be carried out at high speed.

[0045] In the invention (6), a second basis is searched so that h_i may be maximum in the following formula,

$$h_i = \{ \langle d \cdot u_i \rangle - (\langle d \cdot u_1 \rangle \langle u_1 \cdot u_i \rangle / \|u_1\|^2)^2 \\ / \{\|u_i\|^2 - (\langle u_i \cdot u_i \rangle) / \|u_1\|^2\}$$

wherein $\langle d \rangle$ is the differential vectors, $\langle u_1 \rangle$is the base extraction vectors corresponding to the first basis, and $\langle u_i \rangle$ is the base extraction vectors for searching the second basis in the invention (3) or (4).

[0046] According to the invention (6), the AOT processing can be done more efficiently and at higher speed in addition to the advantages of the invention (5) , because the calculation result which has been obtained in the first basis search can be used with respect to $\langle d \cdot u_1 \rangle$and $\|u_1\|$ of the numerator, and $\|u_i\|^2$ and $\|u_1\|$ of the denominator.

[0047] In a preferred embodiment of the invention (3) or (4) that is the invention (7), a third basis is searched so that h_i may be maximum in the following formula,

$$h_i = (\langle d \cdot u_i \rangle - \langle d \cdot v_1 \rangle \langle v_1 \cdot u_i \rangle - \langle d \cdot v_2 \rangle \langle v_2 \cdot u_i \rangle)^2$$

$$/\{\|u_i\|^2 - <v_1 \cdot u_i>^2 - <v_2 \cdot u_i>^2\}$$

wherein $<d>$ is the differential vectors, $<v_1>$ is the first orthonormal base vectors, $<v_2>$ is the second orthonormal base vectors, and$<u_i>$is the base extraction vectors for searching the third basis.

[0048] According to the invention (7), the AOT processing can be done more efficiently and at higher speed in addition to the advantages of the invention (5) and (6), because the calculation result which has been obtained in the first and second basis search can be used with respect to ($<d \cdot u_i> - <d \cdot v_1><v_1 \cdot u_i>$) of the numerator, and ($\|u_i\|^2 - <v_1 \cdot u_i>^2$) of the denominator.

[0049] In a preferred embodiment of the invention (6) or (7) that is the invention (8), the base extraction vectors$<u_i>$which match with search conditions are subjected to orthogonal transform with one or more preceding orthonormal basis.

[0050] That is, one orthonormal processing per each base extraction vector$<u_i>$, which is adopted as the basis after the search termination at each stage is carried out, whereby the AOT processing can be done more efficiently and at higher speed.

[0051] In the image encoding method of the invention (9), the norm of each scalar expansion coefficient $\beta_1 \sim \beta_m$ is rearranged in decreasing order, a difference (including 0) between norms adjacent to each other is calculated, and Huffman coding is applied to the obtained difference. In the method, the basis is represented by $\beta_k<u_k>$, wherein k = 1~ m.

[0052] In general, the norm of each scalar expansion coefficient $\beta_1 \sim \beta_m$ can take various value. When the value is rearranged in ascending or descending order and the difference (including 0) between norms adjacent to each other is calculated, each difference is often similar to or same as each other. The more encoding compression is possible by applying the Huffman coding to the difference value.

[0053] In the image encoding method of the invention (10), image data$<R_j>$of coding objective block is encoded instead of the coding of the basis, where the basis is more than certain number. Accordingly, the decoded image quality is improved. In practical, it does not affect the coding compression ratio because such situation is little.

[0054] The above object of the invention can be resolved by the construction, for example, as shown in Fig. 14. That is, the image decoding method of the invention (11) comprises reproducing a DC image corresponding to each block mean value per B pixel from encoding data with respect to the HVQ system, making a part of said DC image a DC nest, reproducing image data$<R_j>$of target block by synthesizing, to DC value DC_J of target block, one or more basis vectors $\beta_k<u_k>$ which is selected from DC nests based on the encoding data, and the lowest n ($n = \log_2 B$) bits of the DC pixel in each sample is set to 0, where the selected block is down-sampled from the DC nest and the block mean value of it is calculated using the samples.

[0055] Accordingly, any fraction less than 1 does not occurs in the block mean value and the block mean value with integer level precision is obtained at high speed.

[0056] According to the image decoding method in the invention (12), where the decoded basis is information with respect to $\beta_k<u_k>$ (k = 1~m), the lowest n ($n = \log_2 B$) bits of the DC pixel per each selected block (U_k) to be read out from the DC nest are set to 0, product-sum calculation of basis $\beta_k<u_k>$ (k = 1~m) is carried out, and the calculated result is divided by the number B of block pixels.

[0057] In the invention (12), the lowest n bits of each selected block (U_k) are set to 0, and hence, even if these are accumulated and added, the addition result becomes multiple of integer of the block size B (e.g. 16). An expansion coefficient β_k is an integer precision. Accordingly, if the cumulative addition result is divided by the number B of the block pixels, block mean value A_j is efficiently obtained by one processing. Therefore, such calculation that the basis vectors $\beta_k<u_k>$ (k = 1- m) are overlapped can be effectively carried out.

[0058] In a preferred embodiment of the invention (11) or (12) that is the invention (13), the lowest n bits of each DC pixel is set to 0, where DC nests are produced from the DC image, whereby processing is effectively carried out.

[0059] The image encoding apparatus of the invention (14) comprises producing a DC image composed of each block mean value by dividing an image data per B pixel into a block, making a part of said DC image a DC nest, and where a differential vector$<d_j>$which is obtained by separating the DC value DC_J from the pixel block to be encoded is over an allowable value Z, calculating one or more orthogonal basis (e.g. $\alpha_k<v_k>$), to which the differential vector$<d_j>$is approximated, by the adaptive orthogonal transform (AOT) using the DC nest, and providing a memory 17 to store the DC nest in which the lowest n ($n = \log_2 B$) bits of the DC pixel are set to 0.

[0060] The image decoding apparatus of the invention (15) comprises reproducing a DC image corresponding to each block mean value per B pixel from encoding data with respect to the HVQ system, making a part of said DC image a DC nest, reproducing image data$<R_j>$of target block by synthesizing, to the DC value DC_J of target block, one or more basis vectors $\beta_k<u_k>$which is selected from DC nests based on the encoding data, and providing a memory 49 to store the DC nest in which the lowest n ($n = \log_2 B$) bits of the DC pixel are set to 0.

[0061] The recording medium of the invention (16) comprises a computer readable recording medium storing a pro-

gram to make a computer to implement the processing described in one of the invention (1) to (13).

[0062] In the Drawings

Fig. 1 is a block diagram showing a conventional image encoder;
Fig. 2 is a flow chart of a conventional adaptive orthogonal transform processing;
Fig. 3 is an image drawing of the conventional adaptive orthogonal transform processing;
Fig. 4 is an image drawing of a conventional mean value separation processing;
Fig. 5 is an explanatory drawing of the principle of the invention;
Fig. 6 is a block diagram showing an image encoder, which is an embodiment of the invention;
Fig. 7 is a flow chart showing a main image encoding processing which is an embodiment of the invention;
Fig. 8 is a flow chart (1) showing an adaptive orthogonal transform processing which is an embodiment of the invention;
Fig. 9 is a flow chart (2) showing an adaptive orthogonal transform processing which is an embodiment of the invention;
Fig. 10 is a flow chart (3) showing an adaptive orthogonal transform processing which is an embodiment of the invention;
Fig. 11 is an explanatory drawing (1) of a DC nest, which is an embodiment of the invention;
Fig. 12 is an explanatory drawing (2) of a DC nest, which is an embodiment of the invention;
Fig. 13 is an image drawing of a compression encoding processing of the expansion coefficient;
Fig. 14 is a block diagram showing an image decoder, which is an embodiment of the invention;
Fig. 15 is a flow chart showing an image decoding processing which is an embodiment of the invention; and
Fig. 16 is an image drawing of an alternating current component prediction, which is an embodiment of the invention.

[0063] Referring to the drawings, suitable embodiments of the invention will be explained in detail. The same sign indicates same or corresponding part through whole drawings.

[0064] In Fig. 6 which is a block diagram showing an embodiment of image encoding apparatus in the invention, 31 is a DC nest production unit which produces the DC nest from a decoding DC image according to the invention, 17 is a DC nest memory which stores the produced DC nest, 32 is an adaptive orthogonal transform (AOT) processing unit which effectively implements AOT processing at high speed, 33 is a coefficient transform unit, and 34 is an encoding unit which can make an expanding coefficient β_k higher compression. The other construction is same as in Fig. 1. The feature of each unit will be apparent from the following explanation of behavior.

[0065] In Fig. 7, which is a flow chart showing a main image encoding processing, which is an embodiment of the invention, an original image data is input in a original image memory 11 at step S1. For example, an objective image of R.G.B. is converted to an image of Y.U.V., which is input in the memory 11. Y is a brightness data, U and V are color difference data. U and V are down-sampled using a brightness mean of 2 pixels in a horizontal direction. As an example, the brightness data Y is composed of vertical 960 $\times$ horizontal 1280 pixels and, for example, 8 bits are allotted to each pixel. The processing of the brightness data Y will be mainly explained in the following but U and V are similarly processed.

[0066] A block mean (DC) value of every 4 $\times$ 4 pixels with respect to all image data is calculated at step S2. The first decimal place is round off at the time. All DC values are encoded by conventional two-dimensional DPCM method, etc. and are output at step S3. At step S4, all DPCM outputs are decoded by IDPCM method to reproduce the DC images, which are stored in a DC image memory 15. This is done to equalize AOT processing conditions in the encoding side with that in the decoding side. At step S5, the DC nest is reproduced from the DC images in the DC nest production unit 31, which is stored in the DC nest memory 17. A range from which the DC nest is cut can be selected by the same manner as conventional one.

[0067] In Fig. 11 (a), the lowest 4 bits of each DC pixel DC_J cut from the DC image memory 15 are masked (are set to 0) which are stored in a nest pixel N_J of the DC nest memory 17. The lowest 4 bits are in relation with 2^4 = B (B = block size 16) or 4 = $\log_2$ B. As such result that the lowest 4 bits are masked, the sum of base extraction block<U_i>is always multiple of integer and a block mean value a_i which is 1/16 of the sum is always an integer. Accordingly, the base extraction vectors<u_i>which are obtained by separating the block mean value a_i from the base extraction block<U_i>are always 0.

[0068] In Fig 11 (a) and (b) , graphs of concrete values are shown as example, in which mean of 4 pixels is used for simplifying the explanation. In Fig. 11 (c), even if a plurality of basis vectors β_k <u_k>are cumulatively added to the DC pixel DC_J of a decoding block<R_j>, a noise is not overlapped as usual because the block mean value of each basis vectors β_k <u_k> is always 0, whereby image quality can be much improved.

[0069] The examples of the value in Fig. 11 are shown in Fig. 12 (a). The sum of the DC pixels A to D is 251 and its mean is 251/4 = 62.75 (non-integer). The lowest 4 bits are masked when the DC pixels A to D are transmitted to the nest pixels A to D, whereby the sum of the nest pixels A to D is 224 and its mean value AV is 224/4 = 56 (integer).

Each element a to d of the base extraction vectors $<u_i>$ which is obtained by separating the mean value 56 of the nest pixels from the nest pixels becomes 24, -24, 8 and -8, respectively. The sum of these elements is 0 (complete mean value separation).

[0070] The same value as in Fig. 12 (a) is shown in Fig. 12 (b), except that the DC pixels A to D are copied into the nest pixels A to D and the lowest 4 bits are masked from the sum of the nest pixels A to D. According to the method, the sum is the multiple of 16 and the block mean value is 60 (integer) . However, according to the method, each element a to d of the base extraction vectors$<u_i>$which is obtained by separating the mean value 60 of the nest pixels from the nest pixels A to D becomes 33, -25, 13 and -10, respectively. The sum of these elements is not 0 (complete mean value separation).

[0071] As shown in Fig. 12 (b), after a part of the DC images is copied into the nest pixels A to D, the lowest 4 bits may be masked from each pixel when the base extraction block$<U_i>$is down-sampled from the DC nest.

[0072] Turning to Fig. 7, each index counter j, J to the original image memory 11 and the DC image memory 15 is initialized to 0 at step S6, wherein j indicates an index counter of the target block$<R_j>$which is encoding object, and J indicates an index counter of the DC pixel. At step S7, the differential vector$<d_j>$is obtained by separating a corresponding decoding DC value DC_J from the target block$<R_j>$. At step S8, it is judged whether the square norm $\| d_j \|^2$ of the differential vector is more than the allowable error Z or not. In case that $\| d_j \|^2$ is not more than Z, 0 is output as the number of the basis at step S17 . In this case, the target block$<R_j>$ is decoded by alternating current component prediction method as described hereinafter. In case that $\| d_j \|^2$ is more than Z, the adaptive orthogonal transform (AOT) processing method as described hereinafter is carried out at step S9.

[0073] At step S10, it is judged whether the number of the basis k produced by the adaptive orthogonal transform is more than 4 or not. According to the actual measurement, statistic result of k = 1 to 3 has been obtained in most cases. Therefore, in case that k is more than 4, "5" is code-output as the number of the basis at step S18 and each pixel value of the target block$<R_j>$is output. In case that k is not more than 4, conversion to expanding coefficient β_k is carried out as described hereinafter at step S11. At step S12, the basis number m, the expanding coefficient β_k and the index information i of non-orthogonal basis vector$<u_i>$each is code-output at step S12.

[0074] At step S13, "1" is added to the counters j and J, respectively. In the step, an addition of 1 to the counter j means renewal of one pixel block. It is judged at step S14 whether j is not less than M (the number of all image blocks) or not. In case that j is less than M, turning to step S7 and same encoding processing is repeated with respect to a next target block$<R_j>$, followed by same steps. It is judged at step S14 that j is not less than M, then encoding processing, for example, by Huffman method is carried out at step S15 as described hereinafter. Thus, encoding processing of one pixel is terminated.

[0075] In Figs. 8 to 10, each of which is a flow chart (1), (2) or (3) of the adaptive orthogonal transform processing, it is shown that the minimum necessary number of orthogonal basis $\alpha_k <v_k>$ (k=1~m) is effectively obtained at high speed. In the following explanation, the initial differential vector$<d_j>$obtained at the step S7 is represented by $<d>$ and the differential vector to be renewed later is represented by $<d_k>$ (k=1~m).

[0076] A search processing of first basis is shown in Fig. 8. Before explanation of the processing, an idea on calculation for high speed processing will be explained. That is, the first basis is usually obtained as base extraction vector$<u_j>$, which makes a square norm e_i of the difference between the first basis and a differential vector$<d>$minimum, and is represented by the formula (7).

[Numeral 7]

[0077]

$$\begin{aligned} e_i &= \left\| \mathbf{d} - \frac{\langle \mathbf{d} \bullet \mathbf{u}_i \rangle}{\|\mathbf{u}_i\|^2} \mathbf{u}_i \right\|^2 \\ &= \|\mathbf{d}\|^2 - 2\frac{\langle \mathbf{d} \bullet \mathbf{u}_i \rangle^2}{\|\mathbf{u}_i\|^2} + \frac{\langle \mathbf{d} \bullet \mathbf{u}_i \rangle^2}{\|\mathbf{u}_i\|^4} \|\mathbf{u}_i\|^2 \\ &= \|\mathbf{d}\|^2 - \frac{\langle \mathbf{d} \bullet \mathbf{u}_i \rangle^2}{\|\mathbf{u}_i\|^2} \qquad \text{但し、} \quad \mathbf{u}_i = \mathbf{u}_i' \end{aligned} \tag{7}$$

[0078] The first item $\|d\|^2$ of the right side in the formula (7) which is more than 0 is independent of an extracted basis and hence, $<u_i>$ that makes the second item of the right side in the formula (7) maximum can be the first basis. The second item h_i of the right side is represented by the formula (8).

[Numeral 8]

[0079]

$$h_1 = \frac{<d \cdot u_1>^2}{\|u_1\|^2} \tag{8}$$

[0080] A processing for searching and judging the first basis α_k $<v_k>$which makes h_i maximum is explained. At step S22, the fifteen dimensional vector$<d'>$is obtained by subtracting the sixteenth component of$<d>$from the remaining components as a preprocessing to inner product calculation$<d \cdot u_i>$as described hereinafter. At step S22, the inner product$<d' \cdot u_i>$of h_i numerator is obtained with respect to $i = 0 \sim (N-1)$ and is stored in an arrangement $[P_i]\{i = 0 \sim (N-1)\}$.

[0081] More concretely, $<u_i>$is sixteen dimensional vector, but its sixteenth component u_{16} can be represented by linear bond of the remaining fifteen components because the block mean value (sum of all elements) is 0.

[Numeral 9]

[0082]

$$u_1=[u_1, u_2, u_3, \cdots, u_{16}]$$

$$u_1 + u_2 + \cdots + u_{16} = 0$$

$$u_{16} = -(u_1+u_2 + \cdots + u_{15}) \tag{9}$$

[0083] Accordingly, the inner product$<d \cdot u_i>$ of h_i numerator can be calculated from$<d' \cdot u_i>$equivalent thereto, whereby one product/sum calculation can be omitted which corresponds to 8192 calculations with respect to total of i.

[Numeral 10]

[0084]

$$\begin{aligned}\langle \mathbf{d} \bullet \mathbf{u}_i \rangle &= d_1 u_1 + d_2 u_2 + \cdots + d_{15} u_{15} - d_{16}(u_1 + u_2 + \cdots + u_{15}) \\ &= (d_1 - d_{16})u_1 + (d_2 - d_{16})u_2 + \cdots + (d_{15} - d_{16})u_{15} \\ &= \langle \mathbf{d}' \bullet \mathbf{u}_i \rangle \end{aligned} \qquad (10\text{-}1)$$

$$d' = [(d_1 - d_{16}), (d_2 - d_{16}), \cdots, (d_{15} - d_{16})] \qquad (10\text{-}2)$$

[0085] At step S23, the square norm $\|u_i\|^2$ of h_i denominator is obtained with respect to i = 0 ~ (N-1) and is stored in an arrangement $[L_i]$ {i = 0 ~ (N-1)}.

[Numeral 11]

[0086]

$$\|u_i\|^2 = u_1^2 + u_2^2 + \cdots + u_{16}^2 \qquad (11)$$

[0087] The arrangement $[L_i]$ is repeatedly used. At step S 24, a register E = storing a maximum value of h_i, an index counter i = 0 of the base extraction vector<u_i>and a basis number counter k=1 are initialized, respectively.

[0088] At step S25, a value for $h_i = P_i^2 / L_i$ is calculated. Step S 26, it is judged whether h_i is more than E or not. In case that h_i is more than E, E is renewed by h_i at step S27 and i is held in an arrangement $[I_k]$ (k=1). In case that h_i is not more than E, the processing at Step S 27 is skipped.

[0089] At step S28, 1 is added to i and at step S29, it is judged whether i is not less than N (total extraction numbers) or not. In case that i is less than N, turning to step S25 and maximum value search processing is carried out with respect to next h_i similar to above.

[0090] The same processing is repeated and the search of all nest blocks is terminated when i is not less than N. At the time, the index value i of the first basis vector<u_i>which makes h_i maximum is held in an arrangement $[I_k]$.

[0091] At step S30, the first basis vector<u_i>is normalized to be a normalized basis vector<v_i>which is stored in an arrangement $[V_k]$ (k=1). And, a scalar coefficient α_1 (projection shadow of<d>on<v_i>is calculated and is stored in an arrangement $[A_k]$ (k=1).

[0092] At step S31, the differential vector<d>is approximated to the first basis and is renewed by the differential vector<d_1>= <d>- α_1 <v_1>. At step S32, a square norm e= $\| u_1 \|^2$ of new differential vector is calculated and at step S33, it is judged whether e is not more than Z or not. In case that e is not more than Z, the AOT processing is terminated at the step. In case that e is more than Z, the search processing of the second basis is carried out.

[0093] A search processing of the second basis is shown in Fig. 9. Before explanation of the processing, an idea on efficient calculation will be explained. That is, the second basis is usually obtained as orthogonal vector<u_j'>which makes a square norm e_j of the difference between the second basis and a differential vector<d_1> minimum, and is represented by the formula (12).

[Numeral 12]

[0094]

$$
\begin{aligned}
e_i &= \left\| \mathbf{d}_i - \frac{\langle \mathbf{d}_i \bullet \mathbf{u}_i' \rangle}{\|\mathbf{u}_i'\|^2} \mathbf{u}_i' \right\|^2 \\
&= \|\mathbf{d}_i\|^2 - 2\frac{\langle \mathbf{d}_i \bullet \mathbf{u}_i' \rangle^2}{\|\mathbf{u}_i'\|^2} + \frac{\langle \mathbf{d}_i \bullet \mathbf{u}_i' \rangle^2}{\|\mathbf{u}_i'\|^4} \|\mathbf{u}_i'\|^2 \\
&= \|\mathbf{d}_i\|^2 - \frac{\langle \mathbf{d}_i \bullet \mathbf{u}_i' \rangle^2}{\|\mathbf{u}_i'\|^2}
\end{aligned} \tag{12}
$$

[0095] The orthogonal vector$<u_i'>$is obtained by orthogonal transform of the second base extraction vector$<u_i>$to the first normalized basis vector$<v_1>$.

[Numeral 13]

[0096]

$$u_i' = u_i - \frac{<u_i \cdot v_1>}{\|v_1\|^2} v_1 = u_1 - \langle u_1 \cdot v_1 \rangle v_1 \tag{13}$$

[0097] The first item $\|\mathbf{d}\|^2$ of the right side in the formula (12) which is more than 0 is independent of an extracted basis and hence,$<u_i'>$that makes the second item of the right side in the formula (12) maximum can be the second basis. The second item h_i of the right side is represented by the formula (14).

[Numeral 14]

[0098]

$$h_i = \frac{<d_1 \cdot u_1'>^2}{\|u_i'\|^2} \tag{14}$$

[0099] According to the formula (14), h_i can be calculated but the denominator of the formula (14) may be transformed in order to effectively utilize the calculation result in Fig. 8. That is, if the orthogonal vector$<u_i'>$of the h_i numerator is represented by the base extraction vector$<u_i>$, the h_i numerator can be represented by the formula (15).

[Numeral 15]

[0100]

$$
\begin{aligned}
\langle \mathbf{d}_1 \bullet \mathbf{u}_i' \rangle^2 &= \langle \mathbf{d}_1 \bullet (\mathbf{u}_i - \langle \mathbf{u}_i \bullet \mathbf{v}_1 \rangle \mathbf{v}_1) \rangle^2 \\
&= (\langle \mathbf{d}_1 \bullet \mathbf{u}_i \rangle - \mathbf{d}_1 \bullet \langle \mathbf{u}_i \bullet \mathbf{v}_1 \rangle \mathbf{v}_1)^2 \\
&= \langle \mathbf{d}_1 \bullet \mathbf{u}_i \rangle^2 \qquad \because \langle \mathbf{d}_1 \bullet \mathbf{v}_1 \rangle = 0
\end{aligned}
\tag{15}
$$

[0101] Further, if the differential vector<d_1>of the formula (15) is represented by the first differential vector<d>, the h_i numerator can be represented by the formula (16).

[Numeral 16]

[0102]

$$
\begin{aligned}
\langle \mathbf{d}_1 \bullet \mathbf{u}_i \rangle^2 &= \langle (\mathbf{d} - \langle \mathbf{d} \bullet \mathbf{v}_1 \rangle \mathbf{v}_1) \bullet \mathbf{u}_i \rangle^2 \\
&= (\langle \mathbf{d} \bullet \mathbf{u}_i \rangle - \langle \mathbf{d} \bullet \mathbf{v}_1 \rangle \langle \mathbf{v}_1 \bullet \mathbf{u}_i \rangle)^2 \\
&= \left(\langle \mathbf{d} \bullet \mathbf{u}_i \rangle - \frac{\langle \mathbf{d} \bullet \mathbf{u}_1 \rangle}{\|\mathbf{u}_1\|} \frac{\langle \mathbf{u}_1 \bullet \mathbf{u}_i \rangle}{\|\mathbf{u}_1\|} \right)^2
\end{aligned}
\tag{16}
$$

[0103] Accordingly, the calculation result $< \mathbf{d} \cdot \mathbf{u}_1 >$ which is obtained in the search of the first basis can be used for calculation of the h_i numerator. Also, when the h_i denominator is transformed, it can be represented by the formula (17).

[Numeral 17]

[0104]

$$
\begin{aligned}
\|\mathbf{u}_i'\|^2 &= \|\mathbf{u}_i - \langle \mathbf{u}_i \bullet \mathbf{v}_1 \rangle \mathbf{v}_1\|^2 \\
&= \|\mathbf{u}_i\|^2 - 2\langle \mathbf{u}_i \bullet \mathbf{v}_1 \rangle^2 + \langle \mathbf{u}_i \bullet \mathbf{v}_1 \rangle^2 \|\mathbf{v}_1\|^2 \\
&= \|\mathbf{u}_i\|^2 - \langle \mathbf{u}_i \bullet \mathbf{v}_1 \rangle^2 \\
&= \|\mathbf{u}_i\|^2 - \left(\frac{\langle \mathbf{u}_i \bullet \mathbf{u}_1 \rangle}{\|\mathbf{u}_1\|} \right)^2
\end{aligned}
\tag{17}
$$

[0105] Accordingly, The calculation result $\|u_i\|^2$, $\|u_1\|$ which is obtained in the first basis search can be used in the calculation of the h_i numerator. When h_i is placed in the formula (14), it can be represented by the formula (18-1) and finally by the formula (18-2).

[Numeral 18]

[0106]

$$h_i = \frac{\left(\langle \mathbf{d} \bullet \mathbf{u}_i \rangle - \frac{\langle \mathbf{d} \bullet \mathbf{u}_1 \rangle}{\|\mathbf{u}_1\|} \frac{\langle \mathbf{u}_1 \bullet \mathbf{u}_i \rangle}{\|\mathbf{u}_1\|} \right)^2}{\|\mathbf{u}_i\|^2 - \left(\frac{\langle \mathbf{u}_i \bullet \mathbf{u}_1 \rangle}{\|\mathbf{u}_1\|} \right)^2} \qquad (18\text{-}1)$$

$$= \frac{\left(P_i - \frac{P_k}{\sqrt{L_k}} \frac{\langle \mathbf{u}_k \bullet \mathbf{u}_i \rangle}{\sqrt{L_k}} \right)^2}{L_i - \left(\frac{\langle \mathbf{u}_k \bullet \mathbf{u}_i \rangle}{\sqrt{L_k}} \right)^2} \qquad (18\text{-}2)$$

[0107] A calculating result of the arrangement $[P_i]$, $[L_i]$ can be used for $P_i = \langle d_1 \cdot u_i \rangle$, $L_i = \|u_1\|^2$, respectively and the preceding result can be used for $P_k = P_i = \langle d \cdot u_1 \rangle$, $\sqrt{L_k} = \sqrt{L_1} = \|u_1\|$. Accordingly, it is in a part of $\langle u_k \cdot u_i \rangle = \langle u_1 \cdot u_i \rangle$ that a calculation is newly required.

[0108] Based on the background as above, a search of the second basis is carried out by the following calculation. That is, at step S41, $P_1 = \langle d \cdot u_1 \rangle$ and $L_1 = \|u_1\|^2$ are held as k = 1 . The result obtained in steps S22 and S23 can be used. The numeral "1" of P_1 means the first basis $\langle u_1 \rangle$ in the index counter i and is held in an arrangement $[I_k]$ at step S27. At step S42, a calculation is carried out by the formula (19) and a result is stored in a register η, κ.

[Numeral 19]

[0109]

$$\eta = \frac{1}{\sqrt{L_k}} \qquad \kappa = P_k \eta \qquad (19)$$

[0110] At step S43, the fifteen dimensional vector $\langle w_1 \rangle$ is obtained by subtracting the sixteenth component of $\langle u_1 \rangle$ from the remaining components as the preprocessing of inner product calculation $\langle u_1 \cdot u_i \rangle$ as described below. At step S44, an inner product $\langle w_k \cdot u_i \rangle$ is calculated with respect to i = 0 ~ (N-1) and is stored in an arrangement $[Q_i]$. At step S45, $(P_i - \kappa Q_i)$ is calculated with respect to i = 0 ~ (N-1) and is stored in and written in over an arrangement $[P_i]$. The calculation result at step S45 is stored in (written in over) an arrangement $[P_i]$, whereby contents of the arrangement $[P_i]$ are gradually renewed on the past calculation result. Further, at step S46, $(L_i - Q_i^2)$ is calculated with respect to i = 0 ~ (N-1) and is stored in and written in over an arrangement $[L_i]$. L_i in the right side is a result of the calculation at step S23. The calculation result at step S46 is stored in and written in over an arrangement $[L_i]$ at step S23, whereby contents of the arrangement $[L_i]$ are gradually renewed on the past calculation result. The repeated calculation of h_i is finally represented by the formula (20).

[Numeral 20]

[0111]

$$h_1 = \frac{(P_1 \cdot \kappa Q_1^2)}{L_1 \cdot Q_1^2} = \frac{P_i^2}{L_i} \quad (20)$$

[0112] At step S24, a register E = 0 holding a maximum value of h_i and an index counter i = 0 of the base extraction vector<u_i>are initialized, respectively and "1" is added to a basis number counter k to be k=2.

[0113] At step S48, $h_i = P_i^2 / L_i$ is calculated. At step S49, it is judged whether h_i is more than E or not In case that h_i is more than E, E is renewed by h_i at step S50 and i is stored in an arrangement [I_k] (k=2) . In case that h_i is not more than E, the processing at step S 50 is skipped.

[0114] At step S51, "1" is added to i and at step S52, it is judged whether i is not less than N or not. In case that i is less than N, turning to step S 42 and the maximum value search processing is carried out with respect to subsequent h_i . When the same procedure was proceeded and i is not less than N, the search of the all nest blocks are terminated. At the time, the index value of the second basis vector<u_i>to make h_i maximum is held in an arrangement [I_k] (k=2).

[0115] At step S53, the second basis vector<u_2>is subjected to orthonormal with<v_1>to be a normalized basis vector<v_2>which is stored in an arrangement [V_k] (k=2). A scalar coefficient α_2 which is a shadow of<d_1>projected to<v_2>is calculated and is stored in an arrangement [A_k] (k=2). The orthonormalization of the basis vector<u_2>and the calculation of the scalar coefficient α_2 are carried out at one time with respect to the above search result, whereby the AOT processing is much simplified at high speed.

[0116] At step S54, the differential vector<d_1>is closed to the second basis and is renewed by the differential vector<d_2>= <d_1> - α_2 <v_2>. At step S55, a square norm e= $\| u_2 \|^2$ of new differential vector is calculated and at step S56, it is judged whether e is not more than Z or not. In case that e is not more than Z, the AOT processing is terminated at the step. In case that e is more than Z, the search processing of the third basis is carried out.

[0117] A search processing of the second basis is shown in Fig. 6. Before explanation of the processing, an idea on efficient calculation will be explained. That is, the third basis is usually obtained as orthogonal vector<u_i'>which makes a square norm e_i of the difference between the second basis and a differential vector<d_2>minimum, and is represented by the formula (21).

[Numeral 21]

[0118]

$$\begin{aligned} e_i &= \left\| \mathbf{d}_2 - \frac{\langle \mathbf{d}_2 \bullet \mathbf{u}_i' \rangle}{\|\mathbf{u}_i'\|^2} \mathbf{u}_i' \right\|^2 \\ &= \|\mathbf{d}_2\|^2 - 2\frac{\langle \mathbf{d}_2 \bullet \mathbf{u}_i' \rangle^2}{\|\mathbf{u}_i'\|^2} + \frac{\langle \mathbf{d}_2 \bullet \mathbf{u}_i' \rangle^2}{\|\mathbf{u}_i'\|^4}\|\mathbf{u}_i'\|^2 \\ &= \|\mathbf{d}_2\|^2 - \frac{\langle \mathbf{d}_2 \bullet \mathbf{u}_i' \rangle^2}{\|\mathbf{u}_i'\|^2} \end{aligned} \quad (21)$$

[0119] The orthogonal vector<u_i'>is obtained by orthogonalization of the third base extraction vector<u_i>to the first normalized basis vector<v_1>and the second normalized basis vector<v_2>.

[Numeral 22]

[0120]

$$u_i'=u_1-<u_1 \cdot v_1>v_1-\langle u_i \cdot v_2\rangle v_2 \qquad (22)$$

[0121] The first item $\|d_2\|^2$ of the right side in the formula (21) which is more than 0 is independent of an extracted basis and hence, $<u_i'>$ that makes the second item of the right side in the formula (21) maximum becomes the third basis. The second item h_i of the right side is represented by the formula (23).

[Numeral 23]

[0122]

$$h_1=\frac{<d_2 \cdot u_1'>^2}{\|u_1'\|^2} \qquad (23)$$

[0123] If the orthogonal vector$<u_i'>$of the h_i numerator is represented by the base extraction vector$<u_i>$, the h_i numerator can be represented by the formula (24).

$$\begin{aligned}\langle \mathbf{d}_2 \bullet \mathbf{u}_i' \rangle^2 &= \langle \mathbf{d}_2 \bullet (\mathbf{u}_i - \langle \mathbf{u}_i \bullet \mathbf{v}_1\rangle \mathbf{v}_1 - \langle \mathbf{u}_i \bullet \mathbf{v}_2\rangle \mathbf{v}_2)\rangle^2 \\ &= (\langle \mathbf{d}_2 \bullet \mathbf{u}_i\rangle - \langle \mathbf{d}_2 \bullet \mathbf{v}_1\rangle\langle \mathbf{u}_i \bullet \mathbf{v}_1\rangle - \langle \mathbf{d}_2 \bullet \mathbf{v}_2\rangle\langle \mathbf{u}_i \bullet \mathbf{v}_2\rangle)^2 \\ &= \langle \mathbf{d}_2 \bullet \mathbf{u}_i\rangle^2 \qquad \because \langle \mathbf{d}_2 \bullet \mathbf{v}_1\rangle = 0 \quad \langle \mathbf{d}_2 \bullet \mathbf{v}_2\rangle = 0 \qquad (24)\end{aligned}$$

[0124] Further, if the differential vector$<d_2>$of the formula (24) is represented by the first differential vector$<d>$, the h_i numerator can be represented by the formula (25).

[Numeral 25]

[0125]

$$\begin{aligned}\langle \mathbf{d}_2 \bullet \mathbf{u}_i\rangle^2 &= \langle (\mathbf{d} - \langle \mathbf{d} \bullet \mathbf{v}_1\rangle \mathbf{v}_1 - \langle \mathbf{d} \bullet \mathbf{v}_2\rangle \mathbf{v}_2) \bullet \mathbf{u}_i\rangle^2 \\ &= (\langle \mathbf{d} \bullet \mathbf{u}_i\rangle - \langle \mathbf{d} \bullet \mathbf{v}_1\rangle\langle \mathbf{v}_1 \bullet \mathbf{u}_i\rangle - \langle \mathbf{d} \bullet \mathbf{v}_2\rangle\langle \mathbf{v}_2 \bullet \mathbf{u}_i\rangle)^2 \qquad (25) \\ &= \left(\langle \mathbf{d} \bullet \mathbf{u}_i\rangle - \frac{\langle \mathbf{d} \bullet \mathbf{u}_1\rangle}{\|\mathbf{u}_1\|}\frac{\langle \mathbf{u}_1 \bullet \mathbf{u}_i\rangle}{\|\mathbf{u}_1\|} - \frac{\langle \mathbf{d} \bullet \mathbf{u}_2'\rangle}{\|\mathbf{u}_2'\|}\frac{\langle \mathbf{u}_2' \bullet \mathbf{u}_i\rangle}{\|\mathbf{u}_2'\|}\right)^2\end{aligned}$$

[0126] Also, when the h_i denominator is transformed, it can be represented by the formula (26).

[Numeral 26]

[0127]

$$\begin{aligned}\left\|\mathbf{u}_i'\right\|^2 &= \left\|\mathbf{u}_i - \left\langle \mathbf{u}_i \bullet \mathbf{v}_1 \right\rangle \mathbf{v}_1 - \left\langle \mathbf{u}_i \bullet \mathbf{v}_2 \right\rangle \mathbf{v}_2\right\| \left\|\mathbf{u}_i - \left\langle \mathbf{u}_i \bullet \mathbf{v}_1 \right\rangle \mathbf{v}_1 - \left\langle \mathbf{u}_i \bullet \mathbf{v}_2 \right\rangle \mathbf{v}_2\right\| \\ &= \left\|\mathbf{u}_i\right\|^2 - \left\langle \mathbf{u}_i \bullet \mathbf{v}_1 \right\rangle^2 - \left\langle \mathbf{u}_i \bullet \mathbf{v}_2 \right\rangle^2 \end{aligned} \qquad (26)$$

[0128] When h_i is placed in the formula (23), it can be represented by the formula (27).

[Numeral 27]

[0129]

$$h_i = \frac{(<d \cdot u_i> - <d \cdot v_1><v_1 \cdot u_1> - <d \cdot v_2><v_2 \cdot u_i>)^2}{\|u_i\|^2 - <u_1 \cdot v_1>^2 - <u_1 \cdot v_2>^2}$$

[0130] The second item of numerator and denominator in the formula (27) has been already calculated and is represented by the formula (28).

$$P_1 = <d \cdot u_1> - <d \cdot v_1><v_1 \cdot u_1> \qquad (28\text{-}1)$$

$$L_1 = \|u_1\|^2 - <u_1 \cdot v_1>^2 \qquad (28\text{-}2)$$

[0131] Accordingly, h_i is represented by the formula (29) in the same manner as in the formula (18-2).

[Numeral 29]

[0132]

$$h_1 = \frac{\left(P_1 - \frac{P_k}{\sqrt{L_k}} \frac{<v_k \cdot u_1>}{\sqrt{L_k}}\right)^2}{L_i - \left(\frac{<v_k \cdot u_1>}{\sqrt{L_k}}\right)^2} \qquad (29)$$

[0133] The formula (29) is same form as the formula (18-2) except that the inner product $<u_k \cdot u_i>$ is changed to $<v_k \cdot u_i>$. Accordingly, each basis hereinafter can be effectively obtained by repeating the same operation as in Fig. 5.

[0134] Based on the above processing, search of the third and following basis is calculated as follows. That is, $P_2 = <d_1 \cdot u_2>$ and $L_2 = \|u_2\|^2$ are hold by k = 2 at stet S61. At step S62, calculation is carried out according to the formula (30) and a result is stored in the registers η and κ.

[Numeral 30]

[0135]

$$\eta = \frac{1}{\sqrt{L_k}} \qquad \kappa = P_k \eta \qquad (30)$$

[0136] At step S63, the fifteen dimensional vector$\langle w_2 \rangle$is obtained by subtracting the sixteenth component of$\langle v_2 \rangle$from the remaining components as the preprocessing of inner product calculation$\langle v_2 \cdot u_i \rangle$as described below. Since each component of$\langle v_2 \rangle$is not an integer, it is necessary that an inner product is calculated in the form of real number. In order to avoid the calculation in the form of real number, each component of$\langle v_2 \rangle$(i.e.$\langle w_2 \rangle$) is multiplied by a constant "a" to make it an integer, in advance.

[0137] At step S 64, an inner product$\langle w_2 \cdot u_i \rangle \eta$ /a is calculated with respect to i = 0 ~ (N-1) and is stored in (written in over) an arrangement $[Q_i]$. At the time, each calculation result is divided by the constant a to put the position of a figure to the former position.

[0138] At step S 65, ($P_i - \kappa Q_i$) is calculated with respect to i= 0 ~ (N-1) and is stored in (written in over) an arrangement $[P_i]$. At step S 46, ($L_i - Q_i^2$) is calculated with respect to i = 0 ~ (N-1) and is stored in (written in over) an arrangement $[L_i]$. The calculation of the formula (29) is represented by the formula (31).

[Numeral 31]

[0139]

$$h_i = \frac{(P_1 - \kappa Q_1)^2}{L_i - Q_1^2} = \frac{P_i^2}{L_i} \tag{31}$$

[0140] At step S 67, a register E = 0 holding a maximum value of h_i and an index counter i = 0 of the base extraction vector$\langle u_i \rangle$are initialized, respectively and "1" is added to a basis number counter k to be k=3.

[0141] At step S68, $h_i = P_i^2 / L_i$ is calculated. At step S69, it is judged whether h_i is more than E or not. In case that h_i is more than E, E is renewed by h_i at step S70 and i is held in an arrangement $[I_k]$ (k=3) . In case that h_i is not more than E, the processing at step S70 is skipped.

[0142] At step S71, "1" is added to i and at step S72, it is judged whether i is not less than N or not. In case that i is less than N, turning to step S68 and the maximum value search processing is carried out with respect to subsequent h_i . When the same procedure was proceeded and i is not less than N, the search of the all nest blocks are terminated. At the time, the index value of the third basis vector$\langle u_3 \rangle$to make h_i maximum is held in an arrangement $[I_k]$ (k=3).

[0143] At step S73, the third basis vector$\langle u_3 \rangle$is subjected to orthonormal transform with$\langle v_1 \rangle$and$\langle v_2 \rangle$to be a normalized basis vector$\langle v_3 \rangle$which is stored in an arrangement $[V_k]$. A scalar coefficient α_3 which is a shadow of$\langle d2 \rangle$projected to$\langle v_3 \rangle$is calculated and is stored in an arrangement $[A_k]$.

[0144] At step S74, the differential vector$\langle d_2 \rangle$is approximated to the third basis and is renewed by the differential vector$\langle d_3 \rangle = \langle d_2 \rangle - \alpha_3 \langle v_3 \rangle$. At step S75, a square norm e= $\| d_3 \|^2$ of new differential vector is calculated and at step S76, it is judged whether e is not more than Z or not. In case that e is not more than Z, the AOT processing is terminated at the step. In case that e is more than Z, turning to the step S61 and the preprocessing and search processing of the fourth and following basis are carried out. It is preferred that the processing to judge whether k is not less than 4 or not is provided (not shown) after the step S76, whereby the AOT processing can be skipped in case that k is not less than 4.

[0145] The AOT processing can be much simplified can be carried out at high speed by the above processing or operation. The actual calculation time is reduced to 1/3 to 1/10 in comparison with conventional methods.

[0146] Referring to Fig. 6, a group of $\alpha_k \langle v_k \rangle$ (k=1~m) is obtained from AOT 32 and the differential vector$\langle d_j \rangle$is approximated within the allowable error Z by the linear bond.

[0147] Further, in the coefficient transform unit 33, the expansion coefficient β_k is obtained to transform the group of $\alpha_k \langle v_k \rangle$ (k=1~m) to $\beta_k \langle u_k \rangle$ (k=1~m) by the following method. That is, when each matrix of the base extraction vector$\langle u_k \rangle$, the expansion coefficient β_k, the orthonormal basis vector$\langle v_k \rangle$and the scalar coefficient α_k is represented by the formula (32),

[Numeral 32]

[0148]

$$\mathbf{U} = [\mathbf{u}_1, \mathbf{u}_2, \cdots \mathbf{u}_m] \qquad \mathbf{B} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_m \end{bmatrix}$$

$$\mathbf{V} = [\mathbf{v}_1, \mathbf{v}_2, \cdots \mathbf{v}_m] \qquad \mathbf{A} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \vdots \\ \alpha_m \end{bmatrix} \qquad (32)$$

a relationship of the matrix is represented by the formula (33).

[Numeral 33]

[0149]

$$UB = VA \qquad (33)$$

[0150] In order to solve the formula with respect to the matrix B, both sides of the formula (33) is multiplied from the left by a transposed matrix U^T of the matrix U as shown by the formula (34).

[Numeral 34]

[0151]

$$U^T UB = U^T VA \qquad (34)$$

The matrix ($U^T U$) is expanded to be the formula (35).

[Numeral 35]

[0152]

$$U^T U = \begin{bmatrix} \mathbf{u}_1 \\ \mathbf{u}_2 \\ \vdots \\ \mathbf{u}_{nk} \end{bmatrix} [\mathbf{u}_1, \mathbf{u}_2, \cdots \mathbf{u}_{nk}]$$

$$= \begin{bmatrix} \mathbf{u}_1 \bullet \mathbf{u}_1 & \mathbf{u}_1 \bullet \mathbf{u}_2 & \cdots & \mathbf{u}_1 \bullet \mathbf{u}_{nk} \\ \mathbf{u}_2 \bullet \mathbf{u}_1 & \mathbf{u}_2 \bullet \mathbf{u}_2 & \cdots & \mathbf{u}_2 \bullet \mathbf{u}_{nk} \\ \vdots & \vdots & \vdots & \vdots \\ \mathbf{u}_{nk} \bullet \mathbf{u}_1 & \mathbf{u}_{nk} \bullet \mathbf{u}_2 & \cdots & \mathbf{u}_{nk} \bullet \mathbf{u}_{nk} \end{bmatrix} \quad (35)$$

[0153] In the formula (35), $<u_i \cdot u_j>$means an inner product, and a square matrix which is a symmetrical to a diagonal element is obtained because$<u_i \cdot u_j>$is equal to $<u_j \cdot u_i>$, and an inverse matrix exists because$\langle u_i \rangle$is different from$\langle u_j \rangle$. Therefore, the inverse matrix $(U^T U)^{-1}$ of the matrix $(U^T U)$ is multiplied from the left of both sides of the formula to obtain the formula (36) and β_k is calculated.

[Numeral 36]

[0154]

$$(U^T U)^{-1} U^T UB = B = (U^T U)^{-1} U^T VA \quad (36)$$

[0155] As explained above, it is unnecessary by transforming the group of the orthonormal basis $\alpha_k <v_k>$ (k=1~m) to the non-orthonormal basis $\beta_k <u_k>$ (k=1~m) that each base extraction vector$\langle u_k \rangle$is subjected to orthogonal transform in decoding side every time, and the differential vector$\langle d_j \rangle$can approximate by adding a multiplied value of them and β_k. Thus, the decoding processing can be simply carried out at high speed.

[0156] A compression encoding processing of the expansion coefficient β_k will be explained.

[0157] Fig. 13 is an image drawing of a compression encoding processing of the expansion coefficient. In Fig. 13 (a), a norm is extracted from the produced $\beta_1 \sim \beta_4$. In Fig. 13 (b), a norm is arranged, for example, in ascending order (β_3, β_2, β_4, β_1) and a difference ($\Delta\beta_3$, $\Delta\beta_2$, $\Delta\beta_4$, $\Delta\beta_1$) is calculated . In Fig . 13 (c), the upper bits are separated by removing the lowest two bits from all bits in the difference of coefficient ($\Delta\beta_3$, $\Delta\beta_2$, $\Delta\beta_4$, $\Delta\beta_1$), and are subjected to Hoffman encoding.

[0158] In the example, two groups of $\Delta\beta_3$ and ($\Delta\beta_2$, $\Delta\beta_4$, $\Delta\beta_1$) exist with respect to the value, and according to Huffman encoding, a code sign of less bit numbers is allotted to ($\Delta\beta_2$, $\Delta\beta_4$, $\Delta\beta_1$) of which generating frequency is more and a code sign of more bit numbers is allotted to $\Delta\beta_3$ of which generating frequency is less. Accordingly, the compression encoding of expansion coefficient β_k is possible. Also, fractions of the lowest bits are omitted by Huffman encoding of the upper bits in difference $\Delta\beta_k$ of the coefficient, whereby possibility of $\Delta\beta_2 = \Delta\beta_4 = \Delta\beta_1$ is high in the upper bits as shown in Fig. 13 (c).

[0159] The lowest two bits of difference $\Delta\beta_k$ is packed with positive and negative code sign bits and an index information (13 bits = 0 ~ 8191) of the basis vectors$\langle u_k \rangle$corresponding to the sign bits in a code sign area of 2 bites fixed length and is output as the fixed length code sign. The output is carried out in the order of $\Delta\beta_3$, $\Delta\beta_2$, $\Delta\beta_4$ and $\Delta\beta_1$ (i.e. u_3 , u_2 , u_4 , u_1) .

[0160] In Fig. 13 (d), each code sign is input in the order of u_3 , u_2 , u_4 and u_1 in decoding side, from which each of

the coefficient $\Delta\beta_3$, $\Delta\beta_2$, $\Delta\beta_4$ and $\Delta\beta_1$ is separated. Further, β_3 is decoded from the first $\Delta\beta_3$, β_2 is decoded by adding $\Delta\beta_2$ to the decoded β_3, β_4 is decoded by adding $\Delta\beta_4$ to the decoded β_2, and then β_1 is decoded by adding $\Delta\beta_1$ to the decoded β_4. The decoding order is not important because $\beta_k <u_k>$is functioned based on the sum (linear bond) of these values.

[0161] The difference can be calculated by arranging the norm in descending order instead of the ascending order.

[0162] The coding processing by the encoding unit 34 will be explained. A prediction difference $\Delta DC_{J,I}$ of DPCM is quantized by a quantization coefficient Q (Z), and only in case that $\Delta DC_{J,I}$ is 0, run length coding is considered, and the prediction difference $\Delta DC_{J,I}$ and the run length coding each is independently subjected to Huffman coding. Only in case that the basis number k is 0, the run length coding is considered, and the basis number k and the run length each is independently subjected to Huffman coding. The coefficient difference $\Delta\beta_k$ is quantized by a constant number Q (e.g. 8) to obtain its quotient, which is subjected to Huffman coding. The code sign bits of the expansion coefficient β_k and the lowest two bits of the coefficient difference $\Delta\beta_k$ are incorporated in the code information i (=13 bits) of the basis vector$<u_k>$to make the fixed length coding sign of 16 bits, which are incorporated in the coefficient difference $\Delta\beta_k$ in ascending (or descending) order and is transmitted. As a whole, row of the coding sign is constituted by incorporating these in appearing order per unit of pixel block. If necessary, a sign EOB is input to show change of pixel blocks.

[0163] Fig. 14 is a block diagram showing an image decoder, which is an embodiment of the invention, and corresponds to the image encoder as shown in Fig. 6. In Fig. 14, 41 is a decoding unit by Huffman, etc., 42 is an alternating current component prediction unit for predicting target blocks$<R_j>$containing the alternating current component from the surrounding DC values DC_J' containing the noticeable pixels DC_J, 43 is the differential vector reproduction unit for reproducing an approximate differential vector$<d_j>$based on the decoding basis $\beta_k <u_k>$ (k=1~m), 44 is the R_j reproduction unit for reproducing target blocks$<R_j>$based on the decoding blocks$<R_j>$, 45 is the reproduced image memory, 46 is the IDPCM unit for IDPCM decoding the decoded DC value, 47 is the DC image memory for storing the DC nest, 48 is the DC nest production unit which is same as in Fig. 2, 49 is the DC nest memory for storing the DC nest, 50 is the selected block buffer for holing the selected blocks$<U_k>$which are down-sampled from the DC nest, 51 is a multiplier for multiplying$<U_k>$by β_k, 52 and 53 are the cumulative addition unit of $\beta_k <u_k>$ (k=1~m), 54 is a means for obtaining a block mean value A_j of cumulative addition values, 55 is a subtractor for separating the block mean value A_j of cumulative addition values, 56 is an approximate vector buffer for holding reproduced approximate differential vector$<d_j>$, and 57 is a means for adding the reproduced approximate differential vector$<d_j>$.

[0164] In Fig. 15, which is a flow chart showing an image decoding processing of an embodiment of the invention, the image coding data is input at step S101. At step S102, each DC value in Y, U and V is decoded by IDPCM method similar to Fig. 6 and DC images are reproduced. At step S103, DC nest is produced from the DC value of Y component. At the time, as shown in fig. 7, the lowest four bits of each DC pixel value DC_J are masked to be each DC nest pixel value N_J. The information such as cut position of the DC images is separately received. At step S104, the index counters j and J to the original image memory 45 and DC image memory 47 are initialized to 0.

[0165] At step S105, coding data of one block image is input. At step S106, it is judged that k is 0 or not. In case that k is 0, the target blocks $<R_j>$ are reproduced by alternating current prediction method as described hereinafter. In case that k is not 0, it is judged at step S107 whether k is not less than 1 and not more than 4 or not.

[0166] In case k is not less than 1 and not more than 4, the differential vector$<d_j>$is inversely quantized at step S112. Since the lowest four bits of the DC nest are previously masked in the embodiment of the invention, the differential vector$<d_j>$is obtained at once by cumulatively adding the product of the selected block$<U_k>$and β_k and by separating the block mean value A_j from the cumulative addition result, whereby the decoding processing is carried out at high speed. At step S113, the DC value DC_J corresponding to thus obtained differential vector$<d_j>$is added.

[0167] In case k is less than 1 and more than 4, the target blocks$<R_j>$are directly produced from the decoding data of the target blocks$<R_j>$at step S108. Thus, the target blocks$<R_j>$of 4 times 4 pixels are reproduced by any methods as above. The reproduced target blocks$<R_j>$are stored in the reproduced image memory 45 at step S109.

[0168] At step S110, "1" is added to the counters j and J, respectively, and at step S111, it is judged whether i is not less than M (all pixel block numbers) or not. In case that i is less than M, turning to step S105 and the decoding and reproducing processing is carried out with respect to subsequent the block image coding data. When the same procedure was proceeded and j is not less than M in the judge at step S111, the decoding processing per one image is terminated.

[0169] Fig. 16 is an image drawing of an alternating current component prediction, which is an embodiment of the invention and is applicable for conventional prediction methods.

[0170] Fig. 16 (A) is a stepwise alternating current component prediction method as described hereinafter. At first stage, each sub-block $S_1 \sim S_4$ is predicted from each DC value of the 4 blocks (U, R, B, L) surrounding the $S_1 \sim S_4$.

$$S_1 = S + (U + L - B - R) / 8$$

$$S_2 = S + (U + R - B - L) / 8$$

$$S_3 = S + (B + L - U - R) / 8$$

$$S_4 = S + (B + R - U - L) / 8$$

[0171] Similarly, $U_1 \sim U_4$, $L_1 \sim L4$, $R_1 \sim R_4$ and $B_1 \sim B_4$ are predicted at the first stage. At second stage, 4 pixels $P_1 \sim P_4$ on S_1 are predicted by using the above method repeatedly.

$$P_1 = S_1 + (U_3 + L_2 - S_3 - S_2) / 8$$

$$P_2 = S_1 + (U_3 + S_2 - S_3 - L_2) / 8$$

$$P_3 = S_1 + (S_3 + L_2 - U_3 -_2) / 8$$

$$P_4 = S_1 + (S_3 + S_2 - U_3 - L_2) / 8$$

[0172] Each 4 pixels $P_1 \sim P_4$ on $S_2 \sim S_4$ are predicted in the same manner. The target blocks<R_j>are reproduced by such two stage processing.

[0173] Fig. 16 (B) is a non-stepwise alternating current component prediction method, which the applicant has been already proposed. In Fig. 16 (B), each of the 4 pixels $P_1 \sim P_4$ on each of the sub-block $S_1 \sim S_4$ is predicted from each DC value of 4 blocks surrounding the noticeable block S at a stroke. At first, each approximation of $S_2 \fallingdotseq S_3 \fallingdotseq S$, $U_3 \fallingdotseq U_2$ and $L_2 \fallingdotseq L$ is carried out to obtain each 4 pixels $P_1 \sim P_4$ on S_1. The approximation is applied to $P_1 \sim P_4$ on S_1 to obtain the formula,

$$\begin{aligned} P_1 &= S_1 + (U_3 + L_2 - S_3 - S_2) / 8 \\ &= S_1 + (U + L - S - S) / 8 \end{aligned}$$

[0174] The above formula, $S_1 = S + (U + L - B - R) / 8$, is substituted for the formula, $P_1 = S_1 + (U + L - S - S) / 8$, P_1 on S_1 is finally represented by the formula,

$$P_1 = S + (2U + 2L - 2S - B - R) / 8$$

And, P_2 on S_1 is represented by the formula,

$$\begin{aligned} P_2 &= S_1 + (U_3 + S_2 - S_3 - L_2) / 8 \\ &= S_1 + (U + S - S - L) / 8 \end{aligned}$$

[0175] The above formula, $S_1 = S + (U + L - B - R) / 8$, is substituted for the formula, $P_2 = S_1 + (U + S - S - L) / 8$, P_2 on S_1 is finally represented by the formula,

$$P_2 = S + (2U - B - R) / 8$$

[0176] Also, P_3 on S_1 is represented by the formula,

$$P_3 = S_1 + (S_3 + L_2 - U_3 - S_2) / 8$$
$$= S_1 + (S + L - U - S) / 8$$

[0177] The above formula, $S_1 = S + (U+L-B-R) / 8$, is substituted for the formula, $P_3 = S_1 + (S + L-U-S) / 8$, P_3 on S_1 is finally represented by the formula,

$$P_3 = S + (2L-B-R) / 8$$

Further, P_4 on S_1 is represented by the formula,

$$P_4 = S_1 + (S_3 + S_2 - U_3 - L_2) / 8$$
$$= S_1 + (S + S-U-L) / 8$$

[0178] The above formula, $S_1 = S + (U+L-B-R) / 8$, is substituted for the formula, $P_4 = S_1 + (S + S-U-L) / 8$, P_4 on S_1 is finally represented by the formula,

$$P_4 = S + (2S-B-R) / 8$$

[0179] Accordingly, 4 pixels $P_1 \sim P_4$ on S_1 can be non-stepwise obtained by the formulae at a stroke.

$$P_1 = S + (2U + 2L-2S-B-R) / 8$$

$$P_2 = S + (2U-B-R) / 8$$

$$P_3 = S + (2L-B-R) / 8$$

$$P_4 = S + (2S-B-R) / 8$$

[0180] Each 4 pixels $P_1 \sim P_4$ on $S_2 \sim S_4$ is obtained in the same manner.

[0181] The embodiments of the invention are explained by using the several examples, but it is apparent that the invention should notbelimitedthereto. It is to be appreciated that those skilled in the art can change or modify the embodiments in such point as construction, control, processing or a combination thereof without departing from the scope and spirit of the invention.

[0182] According to the invention, high image quality can be obtained by the improvement of the DC nest and high speed encoding can be achieved by the means for the AOT calculation. Therefore, the method of the invention much contributes to the attainment of high image quality and high speed encoding in the HVQ system.

Claims

1. In an image encoding method which comprises producing a DC image composed of each block mean value by dividing an image data per B pixel into a block, making a part of said DC image a DC nest, and where the differential vector which is obtained by separating the DC value from the pixel block to be encoded is over an allowable value, calculating one or more orthogonal basis, to which the differential vector is approximated, by the adaptive orthogonal transform using the DC nest, the improvement which comprises setting the lowest n ($n = \log_2 B$) bits of the DC pixels in each sample to 0, where the base extraction blocks are down - sampled from the DC nest and the block mean value thereof is calculated using the samples.

2. The method according to Claim 1, wherein the lowest n bits of each DC pixels are set to 0, where the DC nest is produced from the DC image.

3. The method according to Claims 1 and 2, wherein a base extraction vector is produced to which the differential vector approximates by separating the block mean value from the base extraction block in which n bits of the DC pixels are set to 0.

4. The method according to Claim 3, optional elements of base extraction vectors$<u_i>$are replaced by linear bond of the remainder elements and the inner product of the base extraction vectors and the other optional vectors$<w>$are calculated by the formula.

$$<w \cdot u_i> = (w_1 - w_{16})\, u_1 + (w_2 - w_{16})\, u_2 + \cdots + (w_{15} - w_{16})\, u_{15}$$

5. The method according to Claims 3 and 4, wherein a first basis is searched so that h_i may be maximum in the following formula,

$$h_i = <d \cdot u_i>^{2} / \|u_i\|^2$$

wherein$<d>$is the differential vectors and$<u_i>$is the base extraction vectors.

6. The method according to Claims 3 and 4, wherein a second basis is searched so that h_i may be maximum in the following formula,

$$h_i = \{ <d \cdot u_i> - (<d \cdot u_1> <u_1 \cdot u_i> / \|u_1\|^2)^2 / \{ \|u_i\|^2 - (<u_1 \cdot u_i>) / \|u_1\|^2 \}$$

wherein$<d>$is the differential vectors, $<u_1>$ is the base extraction vectors corresponding to the first basis, and$<u_i>$is the base extraction vectors for searching the second basis.

7. The method according to Claims 3 and 4, wherein a third basis is searched so that h_i may be maximum in the following formula,

$$h_i = (<d \cdot u_i> - <d \cdot v_1> <v_1 \cdot u_i> - <d \cdot v_2> <v_2 \cdot u_i>)^2 / \{ \| u_i \|^2 - <v_1 \cdot u_i>^2 - <v_2 \cdot u_i> \}^2$$

wherein $<d>$is the differential vectors, $<v_1>$is the first orthonormal base vectors, $<v_2>$ is the second orthonormal base vectors, and$<u_i>$ is the base extraction vectors for searching the third basis.

8. The method according to Claims 6 and 7, wherein the base extraction vectors$<u_i>$which match with search conditions are subjected to orthonormal transform with one or more preceding orthonormal basis.

9. In an image encoding method which comprises producing a DC image composed of each block mean value by dividing an image data per B pixel into a block, making a part of said DC image a DC nest, and where the differential vector which is obtained by separating the DC value from the pixel block to be encoded is over an allowable value, calculating one or more orthogonal basis, to which the differential vector is approximated, by the adaptive orthogonal transform using the DC nest, the improvement which comprises rearranging the norms of each scalar expansion coefficient $\beta_1 \sim \beta_m$ in ascending or descending order, calculating a difference (including 0) between the norms adjacent to each other, and applying Huffman coding to the obtained difference, wherein the basis is represented by $\beta_k <u_k> (k = 1 \sim m)$.

10. In an image encoding method which comprises producing a DC image composed of each block mean value by dividing an image data per B pixel into a block, making a part of said DC image a DC nest, and where the differential vector which is obtained by separating the DC value from the pixel block to be encoded is over an allowable value, calculating one or more orthogonal basis, to which the differential vector is approximated, by the adaptive orthogonal transform using the DC nest, the improvement which comprises encoding an image data of coding objective blocks instead of the coding of the basis, where the basis is more than certain number.

11. In an image decoding method which comprises reproducing a DC image corresponding to each block mean value per B pixel from encoding data with respect to the HVQ system, making a part of said DC image a DC nest, and reproducing image data of target block by synthesizing, to DC value of target block, one or more basis vectors which is selected from DC nests based on the encoding data, the improvement which comprises setting the lowest n ($n = \log_2 B$) bits of the DC pixels in each sample to 0, where the selected block is down-sampled from the DC nest and the block mean value of it is calculated using the samples.

12. In an image decoding method which comprises reproducing a DC image corresponding to each block mean value per B pixel from encoding data with respect to the HVQ system, making a part of said DC image a DC nest, and reproducing image data of target block by synthesizing, to DC value of target block, one or more basis vectors which is selected from DC nests based on the encoding data, the improvement which comprise, where the decoded basis is information with respect to $\beta_k\langle u_k\rangle$ ($k = 1 \sim m$), setting the lowest n ($n = \log_2 B$) bits of the DC pixels per each selected block (U_k) read out from the DC nest to 0, calculating a product-sum of bas is $\beta_k\langle u_k\rangle$($k = 1\sim m$) , and then dividing the calculated result by the block pixel number B.

13. The method according to Claims 11 and 12, wherein the lowest n bits of each DC pixel is made 0, where DC nests are produced from the DC image.

14. In an image encoding apparatus which comprises producing a DC image composed of each block mean value by dividing an image data per B pixel into a block, making a part of said DC image a DC nest, and where a differential vector which is obtained by separating the DC value from the pixel block to be encoded is over an allowable value, calculating one or more orthogonal basis, to which the differential vector is approximated, by the adaptive orthogonal transform using the DC nest, the improvement comprising a memory to store the DC nest in which the lowest n ($n = \log_2 B$) bits of the DC nest pixels are set to 0.

15. In an image decoding apparatus which comprises reproducing a DC image corresponding to each block mean value per B pixel from encoding data with respect to the HVQ system, making a part of said DC image a DC nest, and reproducing image data of target block by synthesizing, to the DC value of target block, one or more basis vectors which is selected from DC nests based on the encoding data, the improvement comprising a memory to store the DC nest in which the lowest n ($n = \log_2 B$) bits of the DC nest pixels are set to 0.

16. A computer readable recording medium storing a program to make a computer to implement the processing according to Claims 1 to 13.

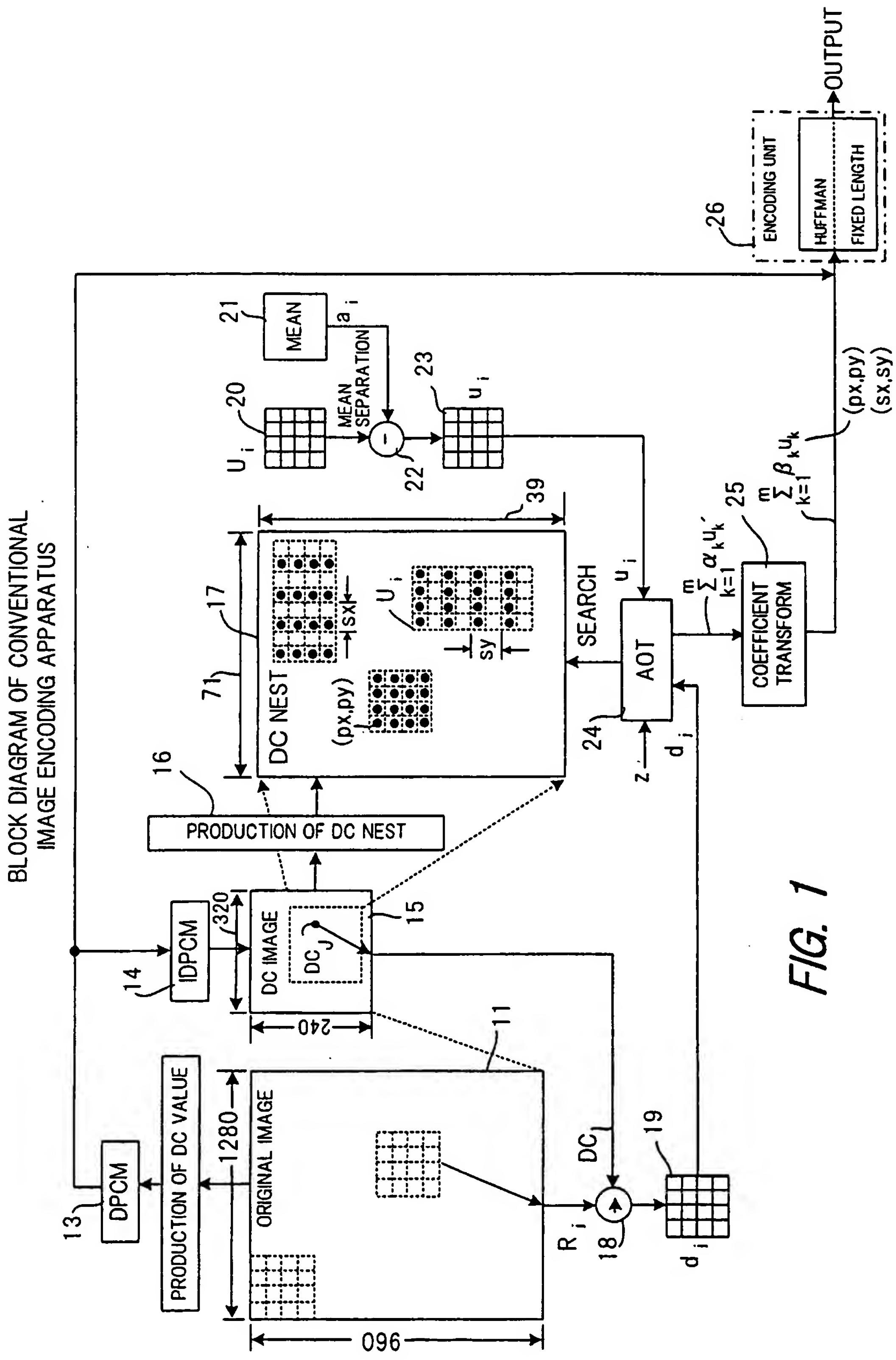

BLOCK DIAGRAM OF CONVENTIONAL IMAGE ENCODING APPARATUS
ORIGINAL IMAGE
1280
960
11
PRODUCTION OF DC VALUE
DPCM
13
IDPCM
14
DC IMAGE
DC_J
320
240
15
PRODUCTION OF DC NEST
16
DC NEST
71
17
39
(px,py)
sx
sy
U_i
SEARCH
AOT
24
z
d_i
u_i
$\sum_{k=1}^{m} \alpha_k u_k'$
COEFFICIENT TRANSFORM
25
$\sum_{k=1}^{m} \beta_k u_k$
(px,py)
(sx,sy)
U_i
20
MEAN
21
a_i
MEAN SEPARATION
22
23
R_i
18
DC
19
ENCODING UNIT
HUFFMAN
FIXED LENGTH
26
OUTPUT

FIG. 1

FLOW CHART OF CONVENTIONAL ADAPTIVE ORTHOGONAL TRANSFORM PROCESSING

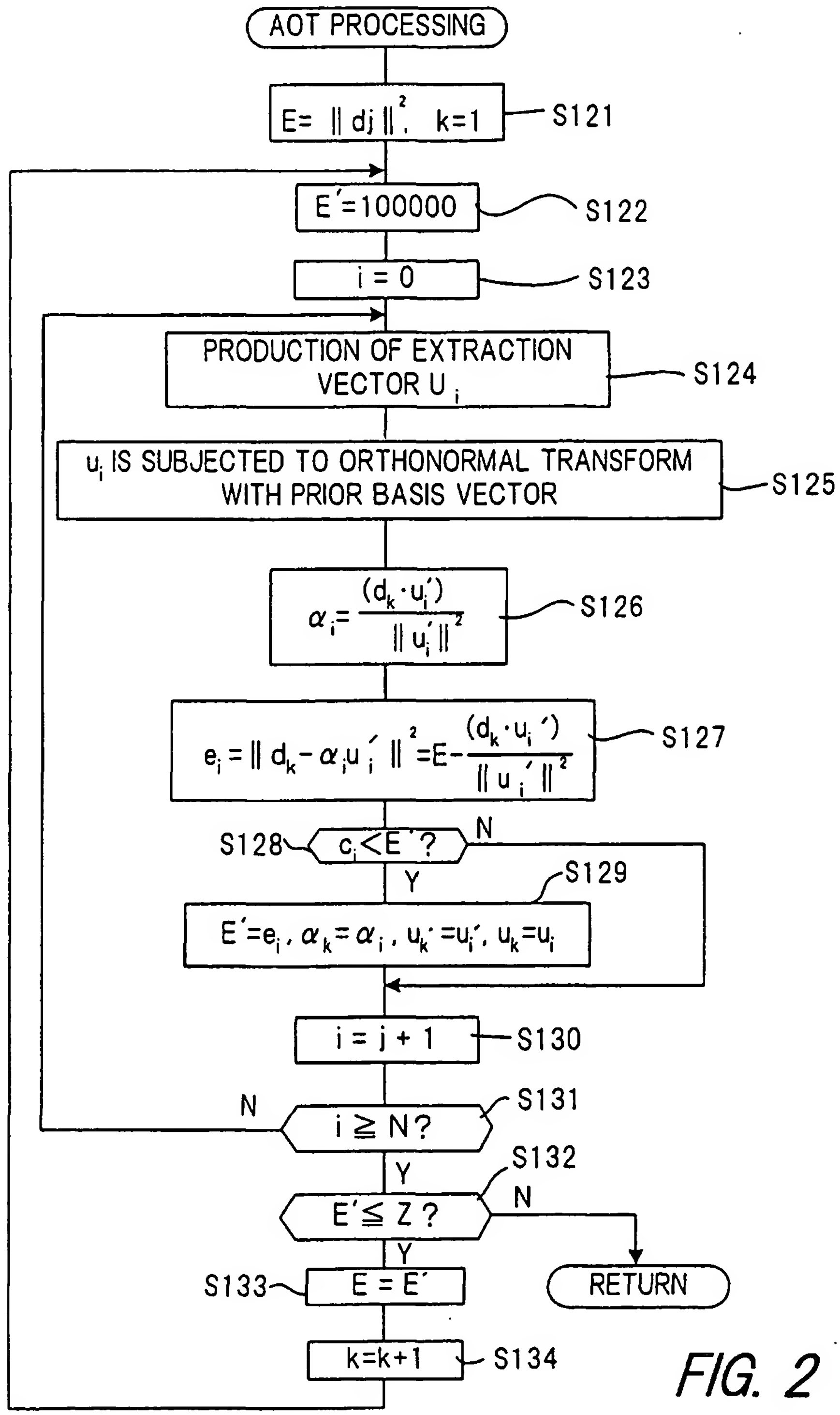


FIG. 2

IMAGE VIEW OF CONVENTIONAL ADAPTIVE ORTHOGONAL TRANSFORM PROCESSING

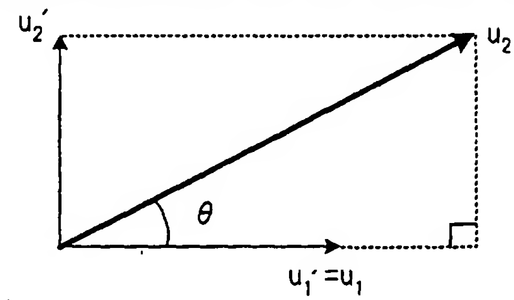


FIG.3A

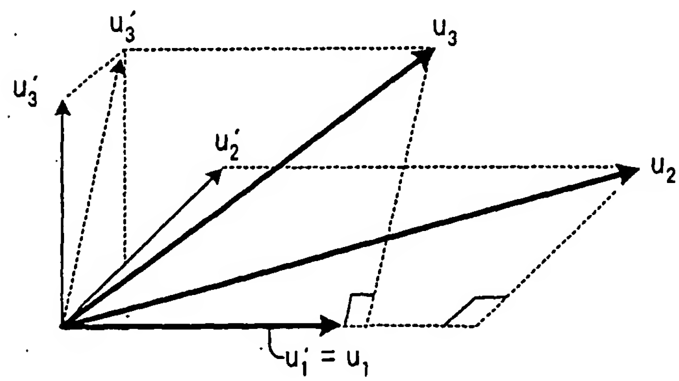


FIG.3B

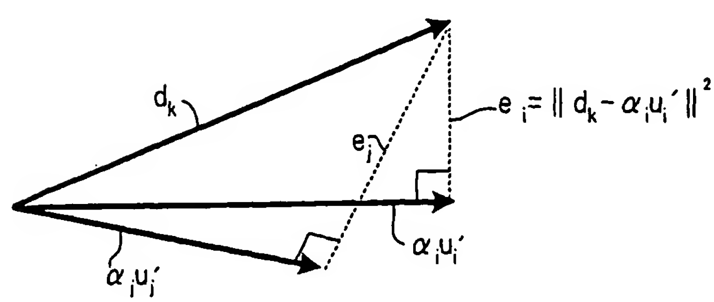


FIG.3C

IMAGE VIEW OF CONVENTIONAL ADAPTIVE ORTHOGONAL TRANSFORM PROCESSING

FIG. 4(a)

FIG. 4(b)

FIG. 4(c)

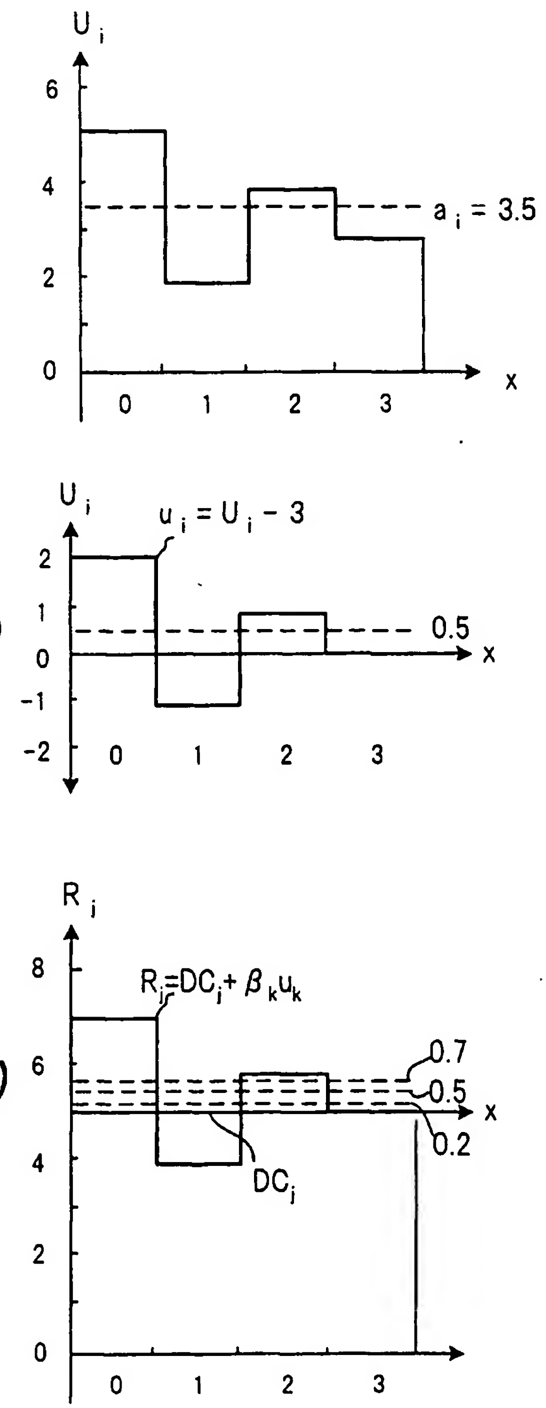


FIG. 5

VIEW FOR EXPLANING PRINCIPLE OF THE INVENTION

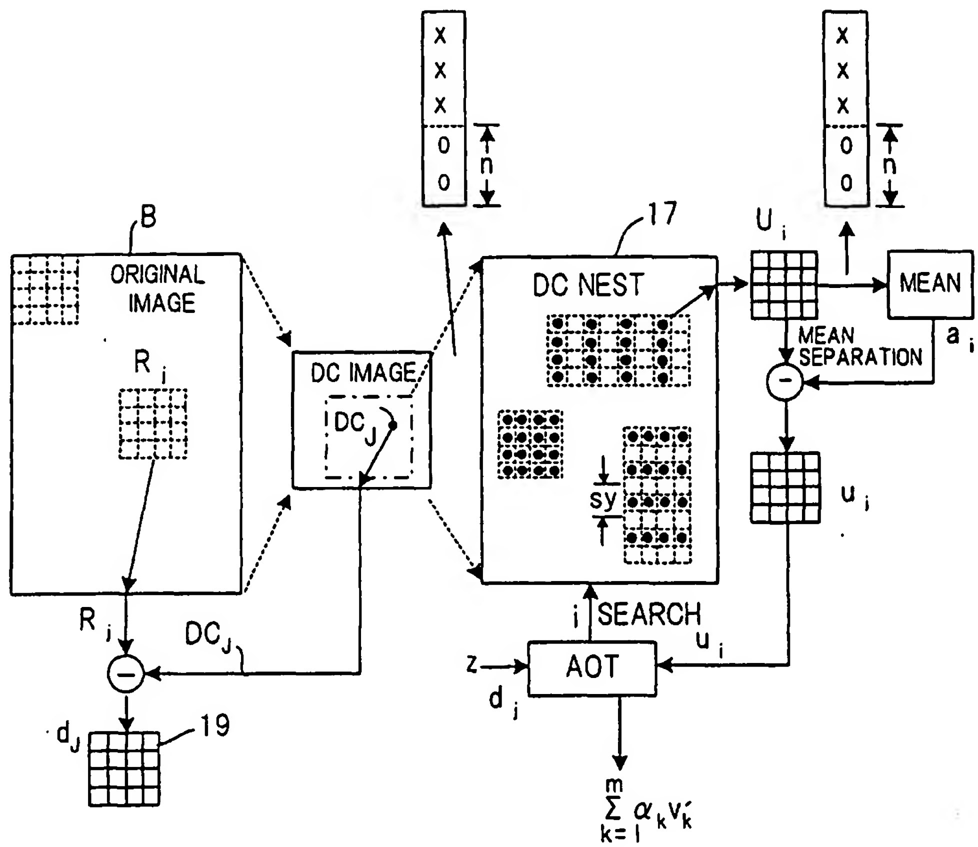
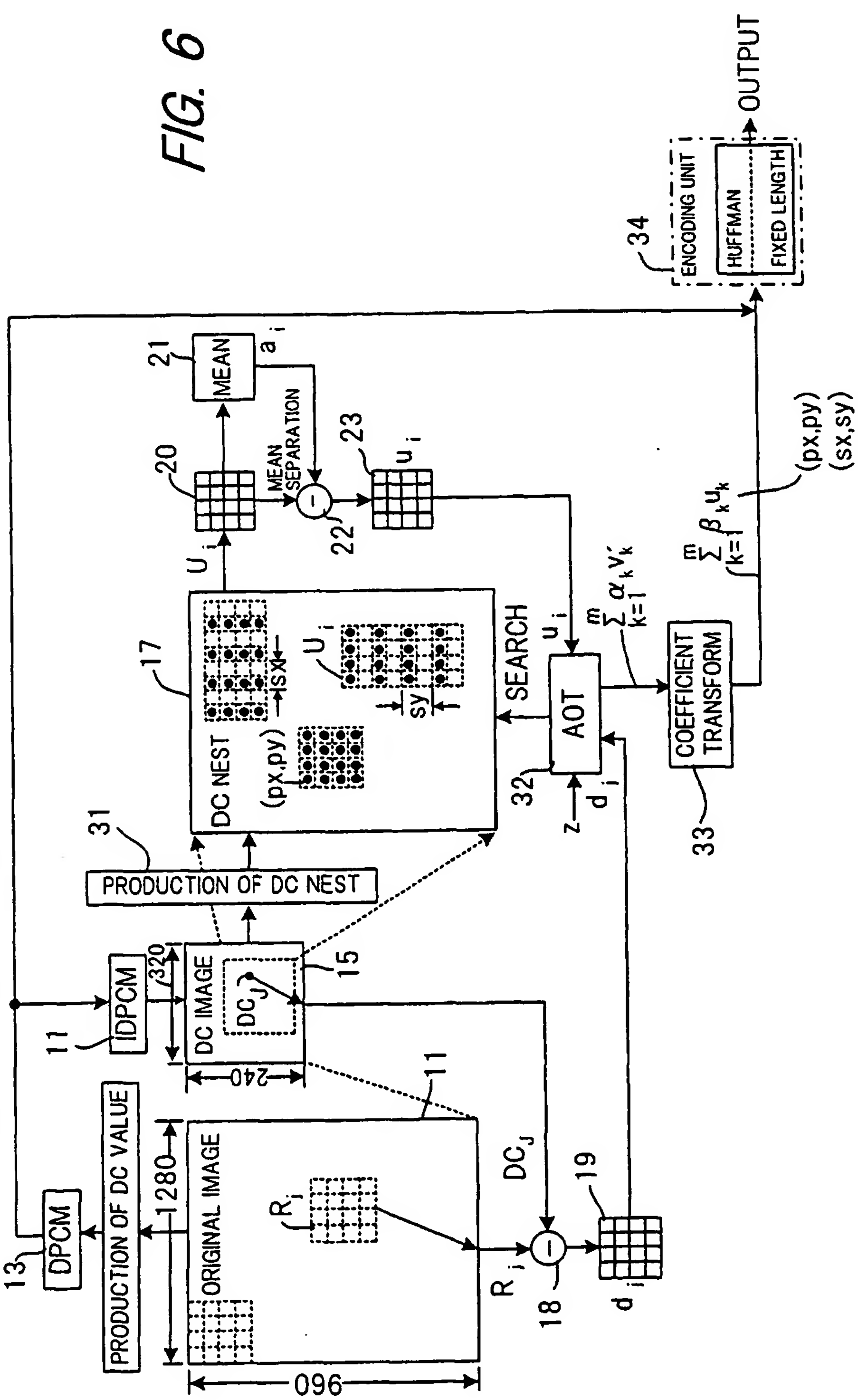


FIG. 6

BLOCK DIAGRAM OF IMAGE ENCODING APPARATUS OF THE INVENTION



BLOCK DIAGRAM OF IMAGE ENCODING PROCESSING IN THE INVENTION

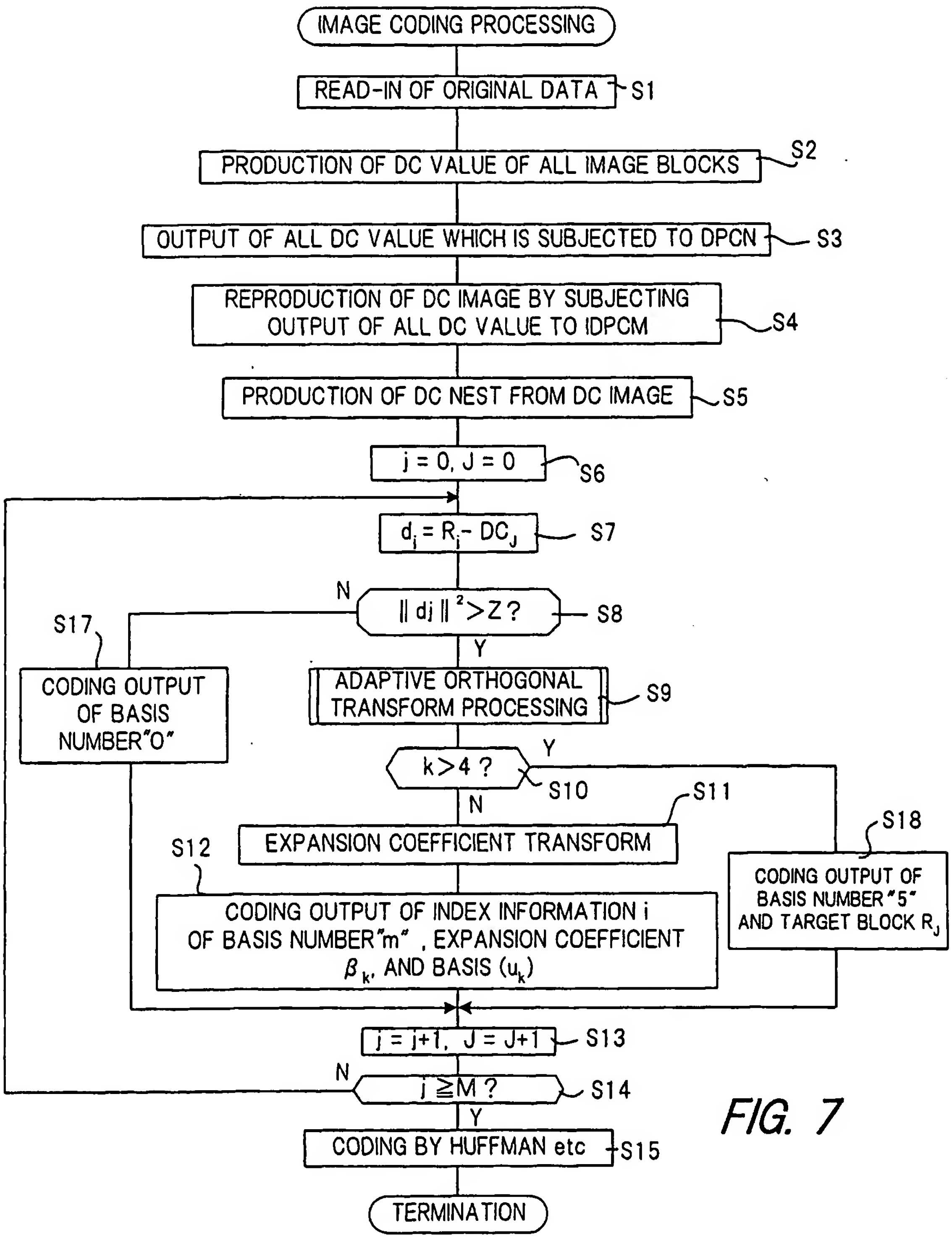


FIG. 7

FLOW CHART(1) OF ADAPTIVE ORTHOGONAL TRANSFORM PROCESSING IN THE INVENTION

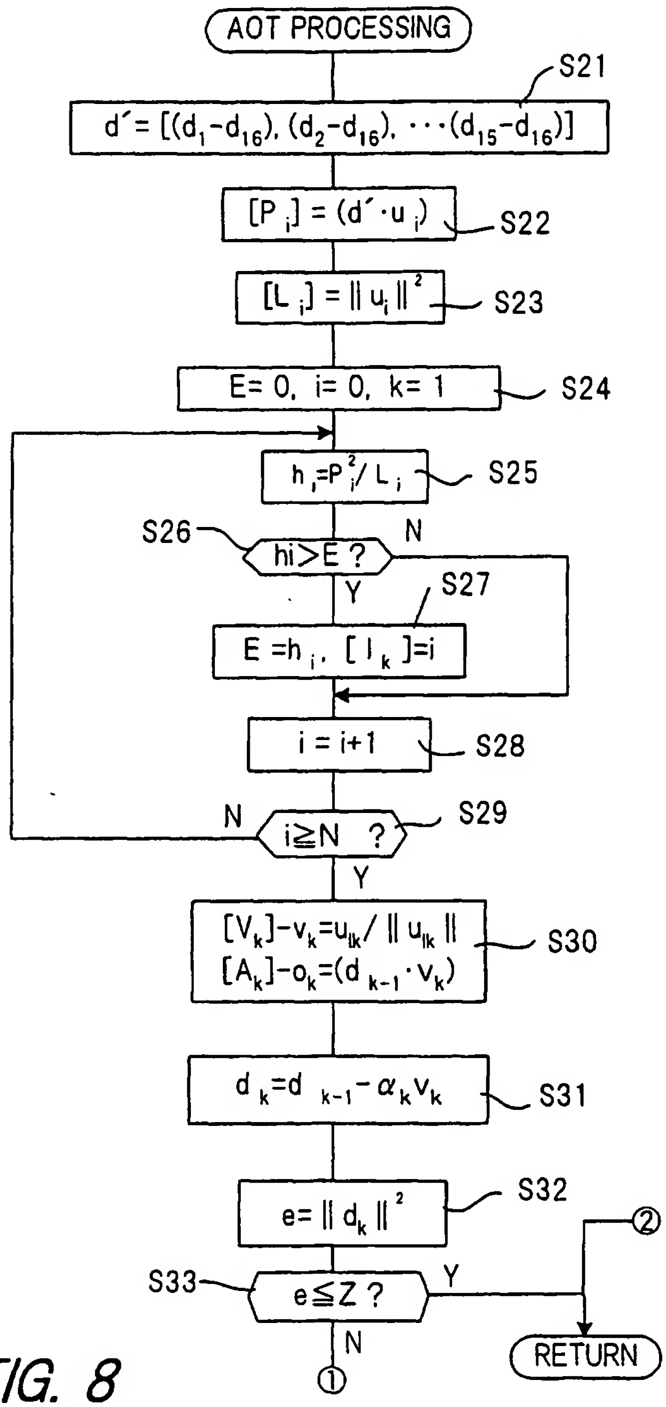


FIG. 8

FLOW CHART(2) OF ADAPTIVE ORTHOGONAL TRANSFORM PROCCESSING IN THE INVENTION

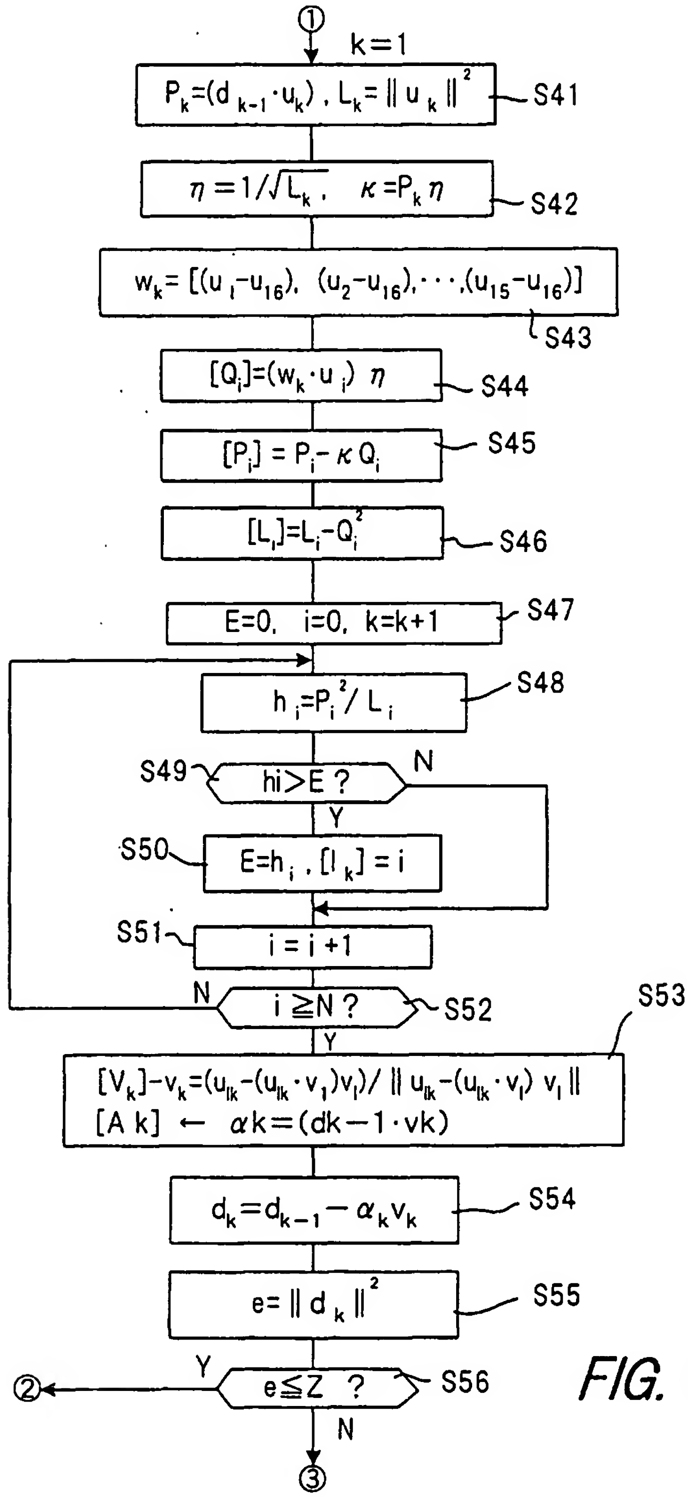


FIG. 9

FLOW CHART(3) OF ADAPTIVE ORTHOGONAL TRANSFORM PROCCESSING IN THE INVENTION

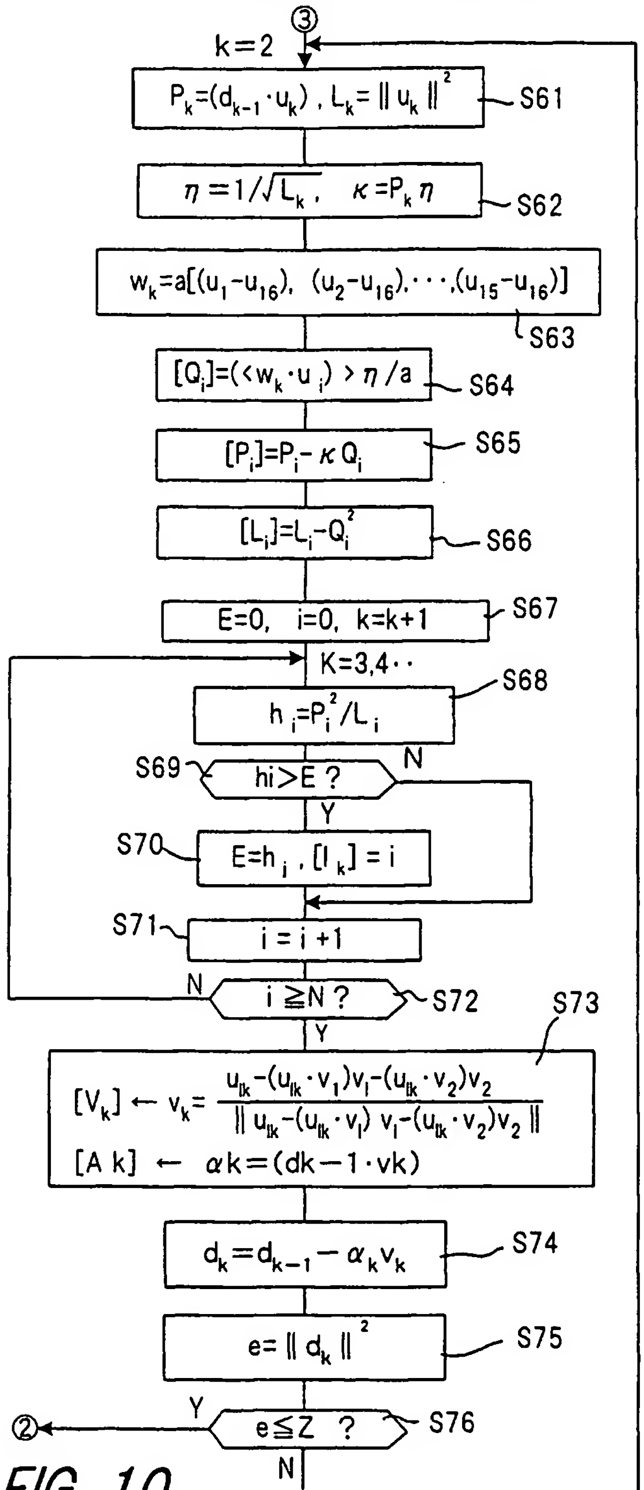


FIG. 10

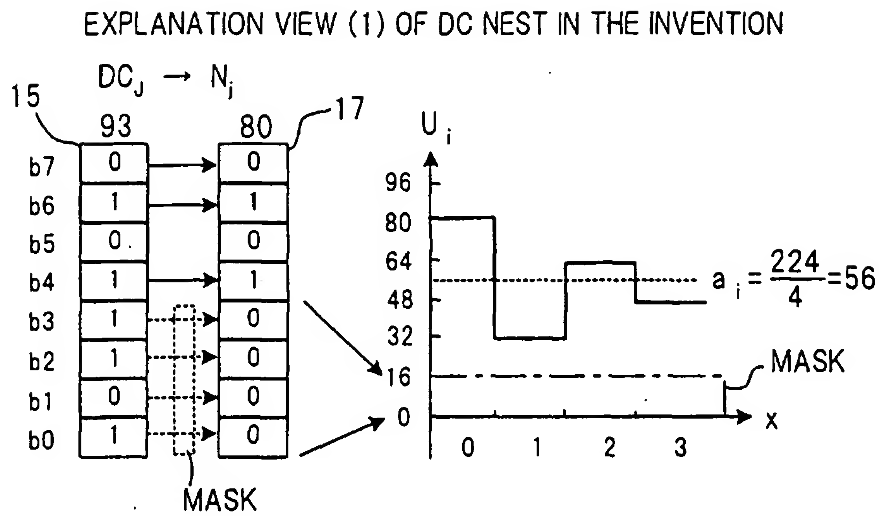


FIG. 11 (a)

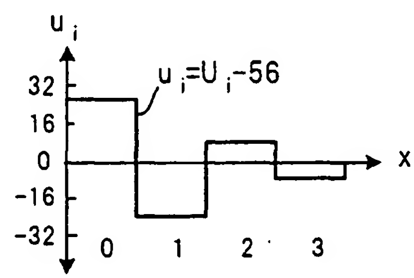


FIG. 11 (b)

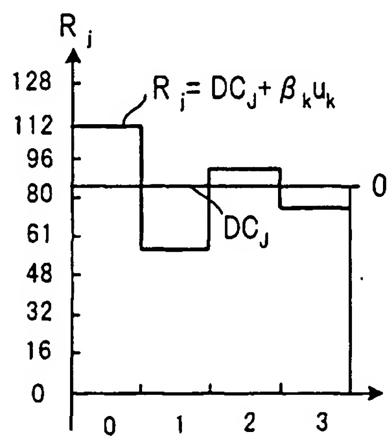


FIG. 11 (c)

EXPLANATION VIEW (2) OF DC NEST IN THE INVENTION

DC

A	B	C	D	SUM	AV
93	35	73	50	251	62.75
0	0	0	0	1	
1	0	1	0	1	
0	1	0	1	1	
1	0	0	1	1	
1	0	1	0	1	
1	0	0	0	0	
0	1	0	1	1	
1	1	1	0	1	

N

A	B	C	D	SUM	AV
80	32	64	48	224	56
0	0	0	0	1	
1	0	1	0	1	
0	1	0	1	1	
1	0	0	1	0	
0	0	0	0	0	
0	0	0	0	0	
0	0	0	0	0	
0	0	0	0	0	

u

a	b	c	d	sum
24	-24	8	-8	0

FIG. 12 (a)

DC

A	B	C	D	SUM	AV
93	35	73	50	251	62.75
0	0	0	0	1	
1	0	1	0	1	
0	1	0	1	1	
1	0	0	1	1	
1	0	1	0	1	
1	0	0	0	0	
0	1	0	1	1	
1	1	1	0	1	

N

A	B	C	D	SUM	AV
93	35	73	50	240	60
0	0	0	0	1	
1	0	1	0	1	
0	1	0	1	1	
1	0	0	1	1	
1	0	1	0	0	
1	0	0	0	0	
0	1	0	1	0	
1	1	1	0	0	

u

a	b	c	d	sum
33	-25	13	-10	11

FIG. 12 (b)

IMAGE DRAWING OF EXPANSION COEFFICIENT ENCODING PROCESSING

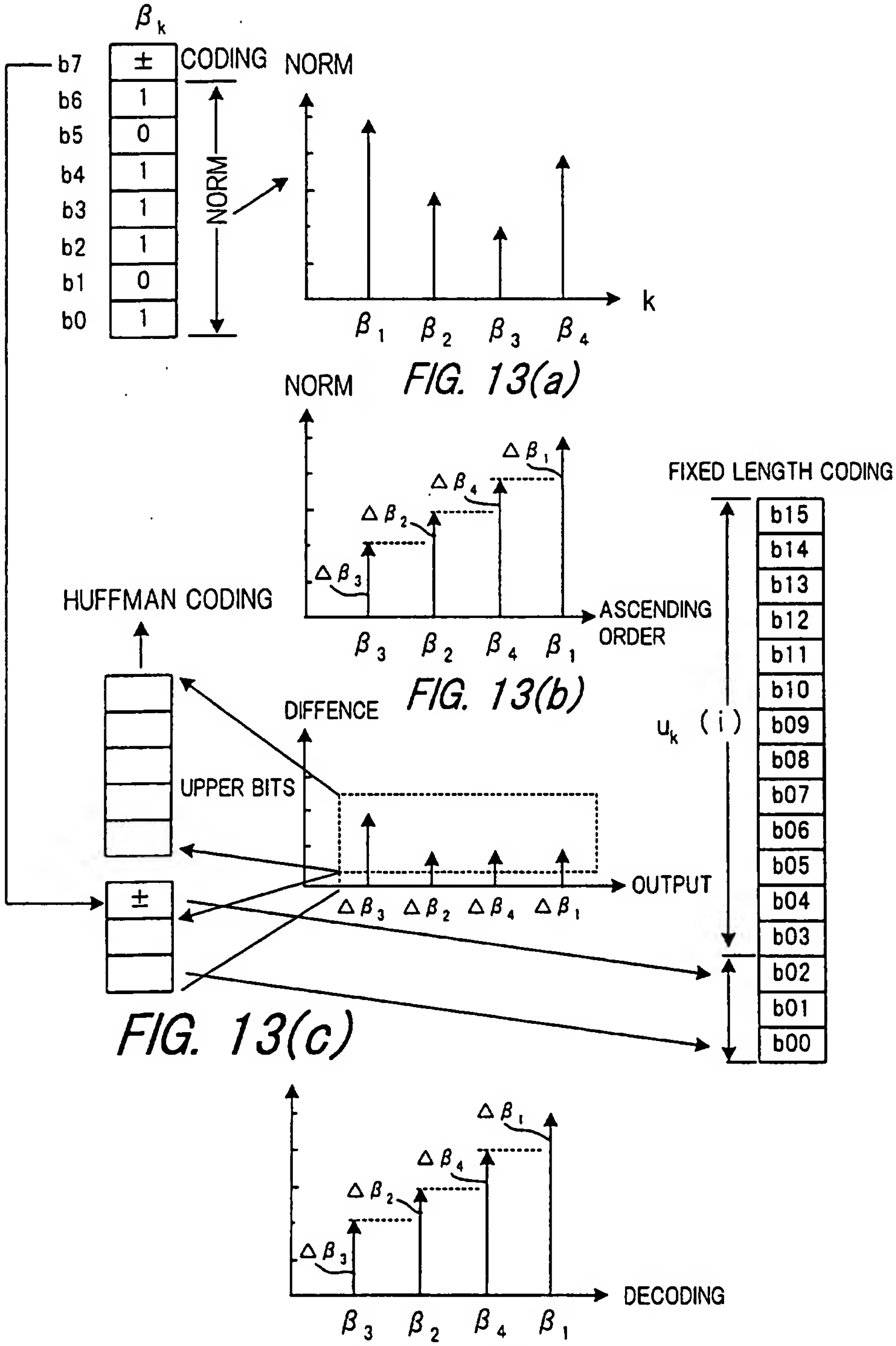


FIG. 13(d)

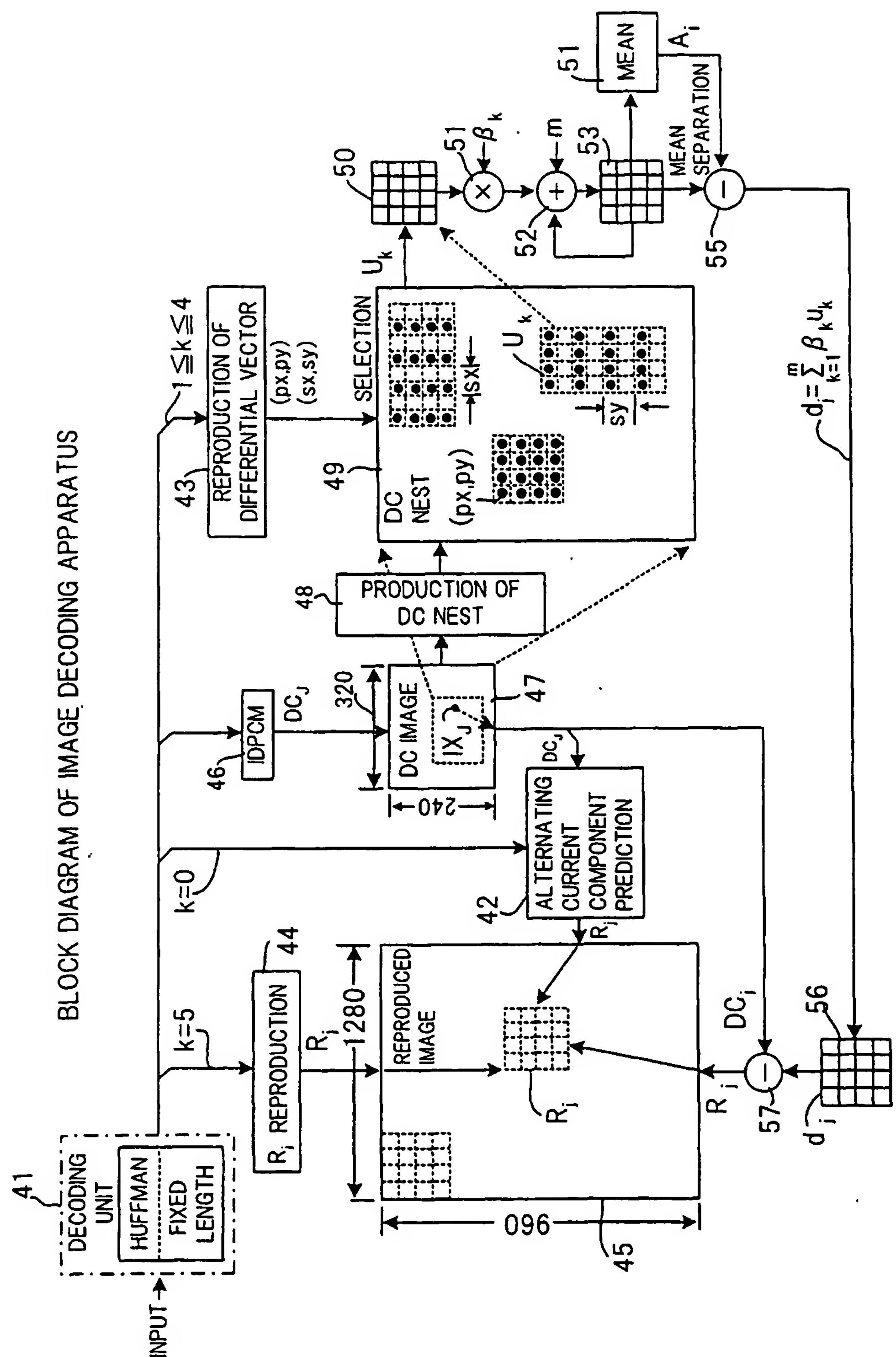

BLOCK DIAGRAM OF IMAGE DECODING APPARATUS
INPUT
41
DECODING UNIT
HUFFMAN
FIXED LENGTH
k=5
k=0
1≦k≦4
44
R_j REPRODUCTION
R_j
1280
REPRODUCED IMAGE
R_j
960
45
42
ALTERNATING CURRENT COMPONENT PREDICTION
DC_J
R_j
46
IDPCM
DC_J
320
DC IMAGE
$|X_J|$
240
47
48
PRODUCTION OF DC NEST
43
REPRODUCTION OF DIFFERENTIAL VECTOR
(px,py)
(sx,sy)
49
DC NEST
(px,py)
SELECTION
sx
sy
U_k
U_k
50
51
β_k
52
m
53
MEAN SEPARATION
51
MEAN
A_j
55
$d_j=\sum_{k=1}^{m}\beta_k u_k$
56
d_j
57
DC_j
R_j

FIG. 14

FLOW CHART OF IMAGE DECODING PROCESSING IN THE INVENTION

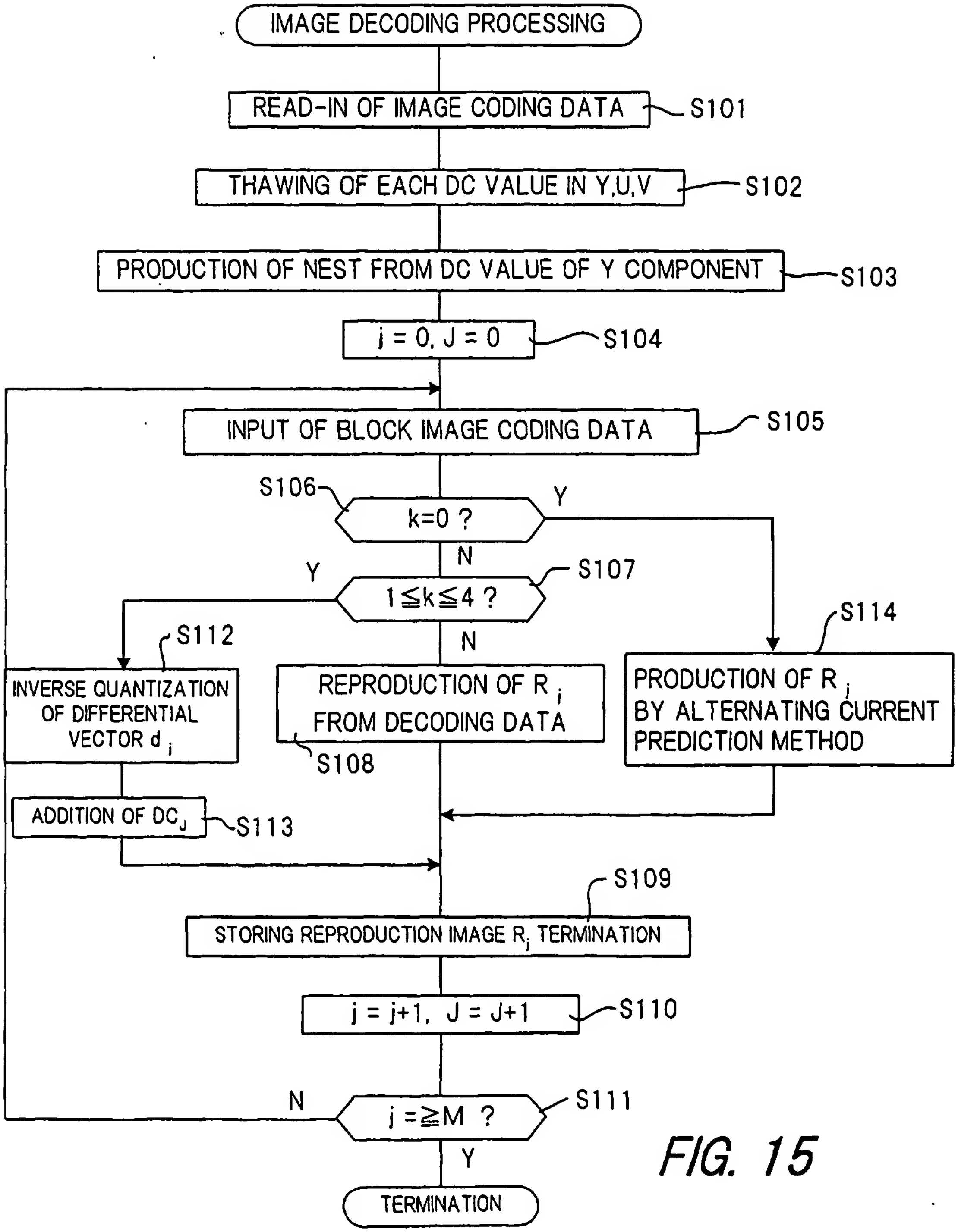


FIG. 15

IMAGE VIEW OF ALTERNATING CURRENT COMPONENT PREDICTION IN THE INVENTION

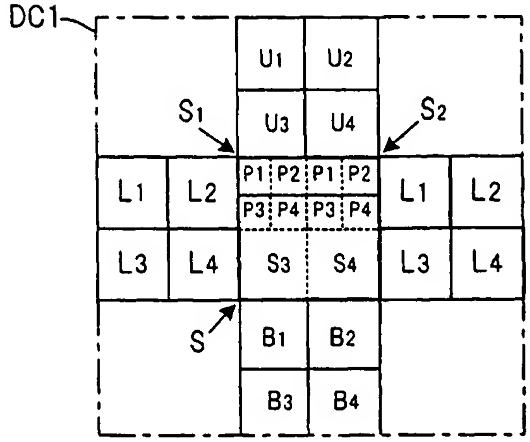


FIG. 16(A)

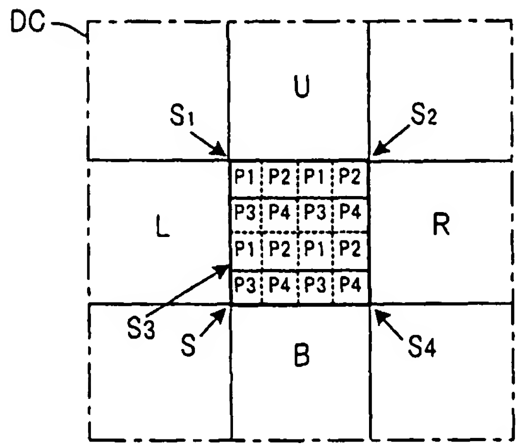


FIG. 16(A)

(19) Europäisches Patentamt
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Office européen des brevets

(11) **EP 1 156 679 A3**

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(54) **Image encoding and decoding method and apparatus, and recording medium in which program therefor is recorded**

(57) The invention relates to an image encoding/decoding method, apparatus thereof and a recording medium in which a program therefor is recorded, whereby the encoding/decoding can be obtained with high image quality at high speed. In an image encoding method which comprises producing a DC image composed of each block mean value by dividing an image data per B pixel into a block, making a part of said DC image a DC nest, and where the differential vector $<d_j>$ which is obtained by separating the DC value DC_J from the pixel block $<R_j>$ to be encoded is over an allowable value Z, calculating one or more orthogonal basis ($\alpha_k <V_k>$), to which the differential vector is approximated, by the adaptive orthogonal transform (AOT) using the DC nest, each of the lowest n ($n = \log_2 B$) bits of base extraction blocks $<U_i>$ which are down-sampled from the DC nest is set to 0 . Further, base extraction vectors $< u_i >$are produced by separating a block mean value a_i from the base extraction blocks $<U_i>$.

BLOCK DIAGRAM OF CONVENTIONAL IMAGE ENCODING APPARATUS

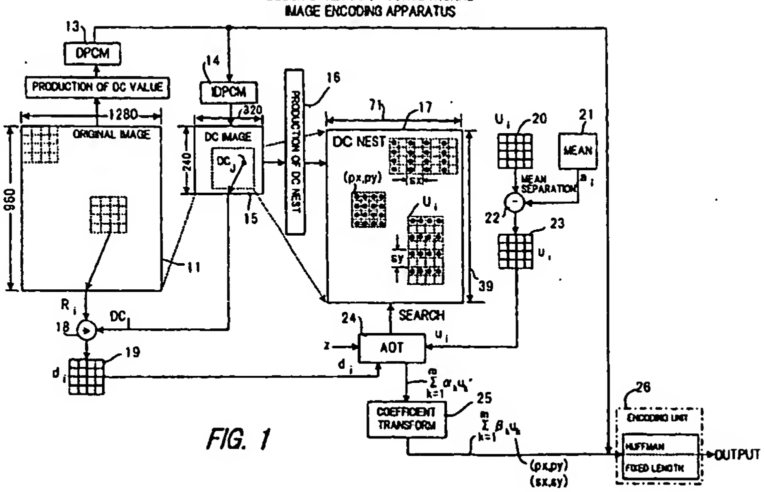

FIG. 1

EP 1 156 679 A3

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European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 1069

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	WO 00 02393 A (HUDSON CO LTD ;MIURA TAKASHI (JP); ITAGAKI FUMIHIKO (JP); KAWASHIM) 13 January 2000 (2000-01-13)	1-16	H04N7/28 H04N7/30
E	& EP 1 104 199 A (HUDSON CO LTD) 30 May 2001 (2001-05-30) * abstract * * page 2, line 13 - page 3, line 25 * * page 4, line 15 - page 5, line 18 * * page 8, line 28 - page 9, line 44 * * figure 1 * ---	1-16	
A	YOU H ET AL: "IMPROVING LIFS IMAGE CODING SCHEME VIA GRAM-SCHMIDT ORTHOGONALIZATION" DENSHI JOHO TSUSHIN GAKKAI GIJUTSU KUNKYU HOKOKU - IEICE TECHNICAL REPORT, DENSHI JOHO TSUSHIN GAKKAI, TOKYO, JP, 1998, pages 37-42, XP002926590 ISSN: 0913-5685 * the whole document * ---	1-16	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	TAKAHASHI T ET AL: "A FAST COMPUTATION ALGORITHM FOR PREDICTING AC COMPONENTS OF IMAGESUSING MEAN VALUES OF BLOCKS" DENSHI JOHO TSUSHIN GAKKAI RONBUNSHI. D-2 - TRANSACTIONS OF THE INSTITUTE OF ELECTRONICS, INFORMATION AND COMMUNICATION ENGINEERSSECTION J-D-2, TOKYO, JP, vol. J81-D-II, no. 4, April 1998 (1998-04), pages 778-780, XP002926594 ISSN: 0915-1923 * the whole document * --- -/--	1-16	H04N

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	8 August 2003	Schoeyer, M

CATEGORY OF CITED DOCUMENTS

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EPO FORM 1503 03.82 (P04C01)

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EUROPEAN SEARCH REPORT

Application Number
EP 01 30 1069

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	PATENT ABSTRACTS OF JAPAN vol. 1995, no. 05, 30 June 1995 (1995-06-30) & JP 07 038760 A (NEC CORP), 7 February 1995 (1995-02-07) * abstract * ---	1-16	
A	HUANG S-C ET AL: "A CONTRAINED VECTOR QUANTIZATION SCHEME FOR REAL-TIME CODEBOOK RETRANSMISSION" IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, IEEE INC. NEW YORK, US, vol. 4, no. 1, 1 February 1994 (1994-02-01), pages 1-7, XP000439479 ISSN: 1051-8215 * the whole document * -----	1-16	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	8 August 2003	Schoeyer, M

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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08-08-2003

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			EP	1104199 A1	30-05-2001
			WO	0002393 A1	13-01-2000
			TW	440805 B	16-06-2001
JP 07038760	A	07-02-1995	US	5841909 A	24-11-1998

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